

Demography and size structure of the giant milkweed shrub *Calotropis procera* (Aiton) W.T. Aiton

Tarek M. Galal¹ · Emad A. Farahat¹ · Maha M. El-Midany¹ · Loutfy M. Hassan¹

Received: 9 June 2015 / Accepted: 23 October 2015 / Published online: 12 November 2015
© Accademia Nazionale dei Lincei 2015

Abstract Studies on plant population demography and size structure provide important base for monitoring and managing plant species. The present study investigated the monthly variation in plant demography, population dynamics and size structure of *Calotropis procera* in urban areas, South Cairo, Egypt. Sixty-three permanent quadrats were selected to represent the monthly variation in the characteristics of *C. procera* population all over one year. The highest plant density was attained in June and the lowest in February and March. The highest biomass was recorded in November, but the lowest in March. The maximum individual's height was recorded from August to January, while the minimum was in late winter. The monthly size distribution indicated that *C. procera* had three different size distributions along the whole year: more or less inverse J-shape, positively skewed and bimodal size distribution. The maximum plant survival was correlated with the availability of soil moisture. The demographic flux indicated that the new branches of plant were mainly formed during April and June, followed by significant mortality in July and October. This study may contribute in planning for managing and conserving this medicinal plant.

Keywords Demographic flux · Natalty · Mortality · Survival · Invasiveness · Calotrope

1 Introduction

Despite the dynamics of semi-desert communities, many shrubs and trees may be considered pioneer species. Their high germination ability, elevated growth rates during early stages and tolerance to high radiation levels allow them to colonize open spaces, thus providing micro-sites for the germination and establishment of many other species under their canopies (Nobel and Franco 1989; Pugnaire et al. 1996). This process contributes to create the heterogeneous landscape that characterizes semi-desert ecosystems. As a result of the above reason, shrubs and trees of semi-desert communities could be considered keystone species on which many community and ecosystem processes depend (Pugnaire et al. 1996).

Demographic studies in plant populations provide useful information on population dynamics and can be used to examine the biotic and abiotic factors affecting them. The information obtained through demographic studies could be used in restoration of degraded lands. Many researchers emphasize the need for studying and understanding the population dynamics of keystone species to find the best way of managing and preserving them within or out of their natural habitat (Bekele 2000). The contribution of demographic studies in assessing the status of a population (Schemske et al. 1994) and the role of plant population studies in examining demographic variation in relation to temporal and spatial environmental variation, succession and nature management has provided important insights (O'Connor 1994).

Although even-aged mono-specific stands of plants are the simplest plant populations, they exhibit some interesting behaviors (Purves and Lawd 2002). As the plants grow, the population develops a size hierarchy, with a few large and many small individuals (Hara 1988), and this pattern

✉ Maha M. El-Midany
maha_elmidany@yahoo.com

¹ Department of Botany and Microbiology, Faculty of Science, Helwan University, Cairo, Egypt

can become reversed, with the plants becoming more similar in size, following the onset of self-thinning (Weiner and Solbrig 1984; El-Midany 2014). Size variation is a feature of virtually all wild populations of plants (Weiner 1990), and because 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 differences may be caused directly or through differences in growth rates due to age differences, generic variation, heterogeneity of resources, herbivory, and competition (Weiner 1985; Galal 2011). Life history studies and demographic models may be valuable for examining the ecological performance of plant species and identifying life history stages where management will be most effective

Calotropis procera (Aiton) W.T. Aiton (Family: Asclepiadaceae) is a xerophytic perennial and evergreen shrub that primarily reproduces by seeds in many soil types and under a wide range of climatic conditions (Frosi et al. 2012; Hassan et al. 2015). Its native range covers South West Asia (India, Pakistan, Afghanistan, Iran, Arabia and Jordan), and Africa (Somalia, Egypt, Libya, south Algeria, Morocco, Mauritania and Senegal) (Parsons and Cuthbertson 2001; Lottermoser 2011). Recently, Farahat et al. (2015) found that this plant has high plasticity in its morphological and reproductive traits by which it replaced many other native species in urban habitats and represent a threat to this ecosystem. To our knowledge, the demographic characteristics of *C. procera* are not well documented in the literature. Therefore, the present study aimed at investigating the monthly variations in the demography of *C. procera* in urban habitats at South Cairo, Egypt; including its size structure, density, biomass, and individual mortality and natality. The effect of abiotic factors on the plant demography is also discussed.

2 Methods

2.1 Study area

The study area was in Helwan city (29°51'N, 31°20'E), which is considered as one of the major industrial urban areas in Cairo. It is located about 25 km south of Cairo's city center near the eastern bank of the River Nile with approximately 500,000 inhabitants. Cement, automobiles, iron, steel, textiles and wood furniture are the main industrial activities in Helwan area. A variety of vegetation types are present in the area, but there is no predominant ground cover (Abdel Hameed et al. 2009). Rainfall in the study area occurs in the cold season from October to May, while summer is practically rainless and the mean annual

rainfall in the area is 4.7 mm year⁻¹. The mean annual minimum temperature is 13.4 °C, maximum temperature is 30.3 °C and average relative humidity is 54.9 % (courtesy of Egyptian Meteorological Organization).

2.2 Selection of stands

Sixty-three permanent quadrats (5 × 5 m) were selected to represent the micro-variations of *C. procera* in urban habitats (residential areas and roadsides) at South Cairo Province (29°51'N, 31°20'E). The sampled quadrats were visited monthly in the period from February 2012 to January 2013 for estimating plant demography and population dynamics of study species.

2.3 Population growth traits

In each quadrat, the number of individuals of *C. procera* was counted to calculate plant density (i.e., number of individuals/unit area). Then the individuals were marked permanently by colored tape to estimate their growth variables. The number of branches of each individual was counted at the first month then three branches were marked for counting their sub-branches. The standing crop phytomass of the above-ground shoots of *C. procera* individuals was calculated monthly from the equation (El-Midany 2014): $y = 0.154x + 1.307$, ($R^2 = 0.81$), where y is the shoot dry weight and x is its volume. The biomass per unit area was calculated using individual plant method (Moore and Chapman 1986): Biomass (kg ha⁻¹) = mean shoot weight (kg dry weight ind.⁻¹) × density (ind. ha⁻¹).

2.4 Size structure

For each marked *C. procera* individual, the height from the ground (H) and average diameter (D) of the crown (based on 2–3 measurements individual⁻¹) were estimated, and their volume was calculated as a cylinder. The size index of each individual was calculated as the average of its height and diameter [$(H + D)/2$] (modified from Crisp and Lange 1976), and used to classify the population in each habitat into six size classes (<0.5, 0.5–1, 1–1.5, 1.5–2.5, 2.5–3.5, >3.5 m). The absolute frequency of individuals, mean height and diameter, and height to diameter ratio (H/D) per individual in each size class were then calculated (Shaltout and Ayyad 1988).

2.5 Species demography

Ninety-four individuals (74 in residential areas and 20 in roadsides) were estimated in the first census at the onset of the sampling process in February 2012, where the number of branches was determined. Afterwards, the number of

living and dead branches as well as the branch survival (the number of branches present at the end of the month as a percent of the total number of branches) was calculated monthly.

The mean natality of individuals (the percentage of newly formed individuals in relation to the total number of individuals), mortality (the percentage of dead individuals in relation to the total number of individuals) and plant survival (the number of individuals present at the end of each month as a percent of the total number of individuals) were determined monthly. At the end of the calendar year, the new successfully established individuals were considered as input to its population. This was referred to as the annual population natality; in addition, the annual mortality was also determined. The amount of change in *C. procera* populations (demographic flux ratio: Fr.) was calculated according to Peter (1980) as: $Fr. = (N - M) / (N + M) = \text{change/flux}$, where N is the natality and M is the mortality. Flux ratio has values from 1.0, which indicates natality of individuals to -1.0 that means individual mortality (El-Midany 2014; Eid 2002; Shaltout and El-Beheiry 2000; Peter 1980).

2.6 Soil analysis

Three soil samples were collected from each habitat (residential area and road sides) at the end of the growing season (January 2013) from the first 50 cm of the superficial soil. Soil texture was determined by using the sieve method and classified according to particles size into: gravels, coarse sand, fine sand, silt and clay. Moisture content was determined using aluminum pans (Allen 1989). Soil extracts were prepared to meet the requirements for different determinants, 1:5 (w/v) soils (g): distilled water (ml). This extract was used to determine pH values using a glass electrode pH meter (Model 9107 BN, ORION type) and electrical conductivity (EC) with conductivity meter 60 Sensor Operating Instruction Corning. Bi-carbonates were determined by titration against 0.1 N HCl using phenol phthalein and methyl orange as indicators. Chlorides were determined by direct titration against silver nitrate solution using 5 % potassium chromate as an indicator. Sulphates were determined turbidimetrically as barium sulphate at 500 nm. N and P were estimated using a spectrophotometer (CECIL CE 1021) by applying Indo-Phenol blue and molybdenum blue methods, respectively (Allen 1989). Calcium and magnesium were determined by titration against 0.01 N versenate solution using mercuric and erichrome black T as indicators. Sodium and potassium were determined using flame photometer (Allen 1989).

2.7 Statistical analysis

The simple linear correlation coefficient (r) was calculated for monthly assessing the relationship between height and diameter of individuals as well as leaf length and width. One-way ANOVA was used to assess the significant monthly variation in plant density and biomass. Paired sampled t test was carried out to assess the significant difference in the soil variables between the two studied habitats (SPSS 2006).

3 Results

3.1 Soil properties

The soil analysis data of the study area indicated significant difference of moisture contents, salinity, P, Cl, Ca, Mg and Na, between residential areas and roadsides (Table 1). The soil mechanical analysis of the two habitats showed comparable texture with the highest values of clay, while moisture content was greater in roadsides than residential area. The residential area had higher concentrations of soil

Table 1 Soil characteristics (mean \pm SD) of the studied urban habitats of *Calotropis procera*

Locations	Residential area	Roadsides	t test
Mechanical analysis			
Gravels (%)	10.5 \pm 2.0	10.8 \pm 0.9	0.16
Coarse sand (%)	2.3 \pm 0.5	3.0 \pm 0.7	1.51
Fine sand (%)	17.4 \pm 5.3	17.7 \pm 0.1	0.11
Silt (%)	3 \pm 0.5	3.6 \pm 0.5	2.78
Clay (%)	66.8 \pm 7.6	64.9 \pm 1.7	0.43
Moisture content (%)	3.3 \pm 0.7	5.4 \pm 0.8	13.34**
Chemical analysis			
PH	7.7 \pm 0.04	7.8 \pm 0.05	3.19
EC ($\mu\text{S cm}^{-1}$)	27.4 \pm 2.3	18.7 \pm 2.4	5.59*
P (mg g^{-1})	0.3 \pm 0.1	0.7 \pm 0.1	4.36*
N (mg g^{-1})	3.0 \pm 2.15	1.7 \pm 1.1	0.75
HCO ₃ (mg g^{-1})	0.6 \pm 0.1	0.7 \pm 0.1	1.31
Cl (mg g^{-1})	143.2 \pm 18.9	75.2 \pm 12.9	6.10*
SO ₄ (mg g^{-1})	31.7 \pm 4.7	26.7 \pm 5.8	1.75
Ca (mg g^{-1})	44.2 \pm 4.6	16.8 \pm 1.6	9.01**
Mg (mg g^{-1})	34 \pm 5.5	7.5 \pm 5.3	4.35*
K (mg g^{-1})	0.6 \pm 0.02	0.7 \pm 0.1	1.31
Na (mg g^{-1})	50.3 \pm 6.3	80.1 \pm 15.6	4.24*

* $p < 0.05$

** $p < 0.01$

salinity, Cl, Ca and Mg, but lower P and Na, than roadside soil.

3.2 Population growth traits

The growth data of *C. procera* populations showed significant monthly variations in the plant density, while the variations in biomass were not significant (Fig. 1). The individuals of *C. procera* reached their highest density (1052.2 individual ha⁻¹) in June, while the lowest (415.6 individual ha⁻¹) was recorded in February and March with an annual mean of 716.2 individual ha⁻¹. The monthly variation in the plant biomass (Fig. 1) indicated that *C. procera* had its highest value (1085.5 kg ha⁻¹) in November, while the lowest (849.1 kg ha⁻¹) was in March, with an annual mean of 959.8 kg ha⁻¹.

The highest total mean of individual's height (1.6 m) was recorded from August to January, while the lowest (1.2 m) was in February and March, with an annual mean of 1.6 m (Table 2). On the other hand, the individuals had their highest mean crown diameter (1.4 m) in November, while the lowest (1.0 m) in February and April, with an annual average of 1.2 m. The correlations between individual's height and diameter were significant in most (ranged between 0.85 in January and 0.92 in April). The ratios of height/diameter were more than unity all over the year; with the highest ratio of 1.8 in January and August, and the lowest of 1.5 in November.

3.3 Size-frequency distributions

The diagrams illustrating the size-frequency distributions of *C. procera* populations represented: (a) bimodal size

distribution in January, November and December; (b) more or less inverse J-shaped in February, March, April and May; and (c) positive skewed distribution in June, July, August, September and October (Fig. 2). The annual size-frequency distribution was positively skewed, with the smallest three size classes contributed about 67.0 % of the total individuals, compared with 33.0 % for the biggest three ones (Fig. 3).

3.4 Plant demographic data

The monthly variations in the branch demography of *C. procera* individuals, including living and dead branches, showed increased number of branches from 16.4 in February 2012 to 25.5 in January 2013 (Table 3). On the average, the highest number of newly formed branches (5.0 = 30.5 % of the total branches) was recorded in September, while the lowest (2.4 = 14.4 % of the total branches) was in June. On the other hand, the dead branches reached their maximum number (5.1 = 31.2 % of the total branches) in May, and the minimum (0.7 = 4.1 % of the total branches) in March. The branch survival decreased gradually from 95.7 % in March to 76.5 % in May and then started to increase again.

The monthly variation in the species demography indicated that *C. procera* did not form new seedlings during winter season (December to March) and the maximum natality (56.2 %) was observed in June (Table 4). *C. procera* exhibited no mortality during February, March, April and June; while its maximum mortality (34.9 %) was recorded in July. The annual natality and mortality were 13.2 and 13.0 %, respectively. Furthermore, *C. procera* had the maximum plant survival (100 %) in March, May,

Fig. 1 Monthly variations in plant density and biomass of *Calotropis procera* in urban area, South Cairo. * $p < 0.05$

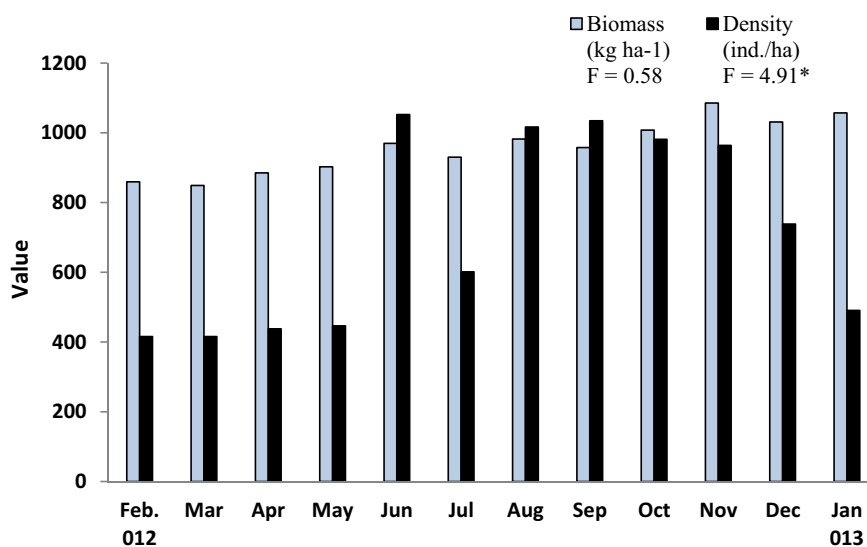


Table 2 Monthly variations in the growth parameters (mean \pm SD) of *C. procera*

Months	<i>H</i> (m)	<i>D</i> (m)	<i>H/D</i>	<i>r</i>	Size index (m)	Volume (m ³)
January	<i>1.6</i> \pm 1.2	1.3 \pm 1.3	<i>1.8</i> \pm 1.0	0.852*	<i>1.5</i> \pm 1.2	8.0 \pm 18.5
February	<i>1.2</i> \pm 1.1	<i>1.0</i> \pm 1.1	1.6 \pm 1.1	0.905*	1.2 \pm 1.1	4.9 \pm 12.9
March	<i>1.2</i> \pm 1.1	<i>1.0</i> \pm 1.0	1.6 \pm 0.9	0.914*	<i>1.1</i> \pm 1.0	<i>4.8</i> \pm 11.9
April	1.3 \pm 1.1	<i>1.0</i> \pm 1.1	1.7 \pm 0.8	0.919*	1.2 \pm 1.1	5.3 \pm 13.1
May	1.3 \pm 1.1	1.1 \pm 1.1	1.6 \pm 0.8	0.885*	1.2 \pm 1.1	5.6 \pm 13.1
June	1.4 \pm 1.1	1.2 \pm 1.2	1.7 \pm 0.9	0.046	1.3 \pm 1.1	6.7 \pm 16.4
July	1.5 \pm 1.1	1.2 \pm 1.1	1.7 \pm 0.9	0.882*	1.3 \pm 1.1	6.0 \pm 14.0
August	<i>1.6</i> \pm 1.2	1.2 \pm 1.2	<i>1.8</i> \pm 1.1	0.096	1.4 \pm 1.1	6.9 \pm 14.7
September	<i>1.6</i> \pm 1.0	1.3 \pm 1.1	1.7 \pm 1.1	0.889*	1.4 \pm 1.1	6.5 \pm 12.9
October	<i>1.6</i> \pm 1.1	1.3 \pm 1.2	1.7 \pm 1.0	0.870*	<i>1.5</i> \pm 1.1	7.3 \pm 15.1
November	<i>1.6</i> \pm 1.2	<i>1.4</i> \pm 1.3	<i>1.5</i> \pm 0.8	0.882*	<i>1.5</i> \pm 1.2	<i>8.5</i> \pm 20.3
December	<i>1.6</i> \pm 1.2	1.3 \pm 1.2	1.7 \pm 1.0	0.879*	1.4 \pm 1.2	7.6 \pm 18.1
Average	1.6 \pm 1.6	1.2 \pm 1.1	1.7 \pm 1.2	0.569**	1.4 \pm 1.2	6.3 \pm 14.2

Minimum and maximum values are italic

H Height, *D* diameter, *r* correlation coefficient between height and diameter, height to diameter ratio (*H/D*)

* $p < 0.05$

** $p < 0.01$

June, August and September; while the minimum (43.1 %) in July.

The monthly demographic flux of *C. procera* indicated exclusive individual natality ($Fr. = 1.0$) in April and June, while mortality ($Fr. = -1.0$) in December and January (Fig. 4). On the other hand, mortality exceeded natality with a negative demographic flux ($0 > Fr > -1$) in July and October, while natality exceeded mortality with positive demographic flux ($0 < Fr < 1$) in May, August, September and November; however the annual mean demographic flux approximated zero.

4 Discussion

Plant density may influence plants habit through its effect on their morphological characters (Shaltout and El-Beheiry 2000). In the present study, the highest plant density was recorded during June, which is characterized by relatively low salinity, high temperature and receiving water discharge from anthropogenic sources, which stimulate seed germination and seedlings emergence. While the lowest plant density was recorded during February with lower temperature and low soil moisture contents. According to Galal (2011) the low plant density could be partially due to eco-physiological constraints, such as reduced growing season, low temperature and low soil moisture content.

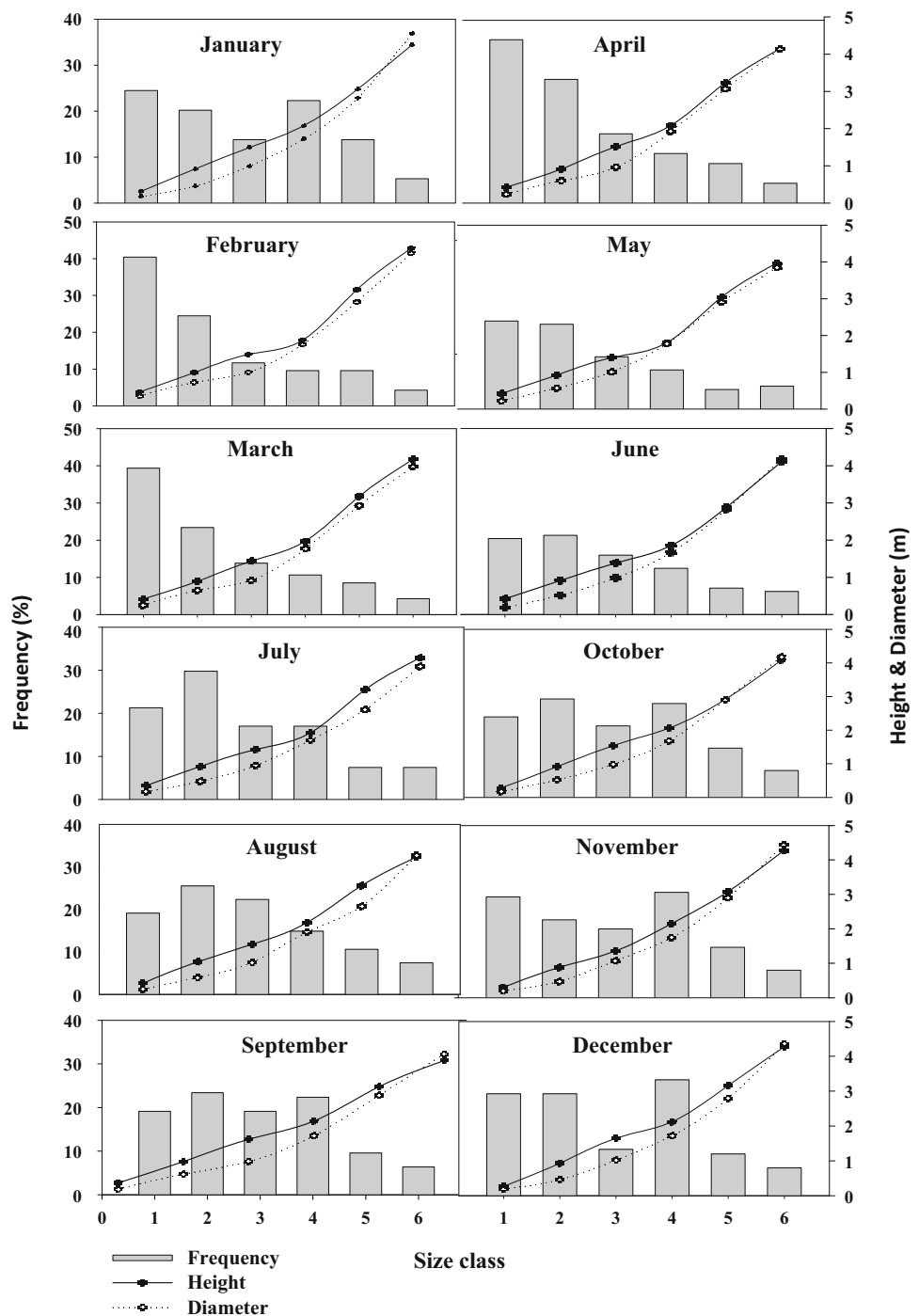
Plant size is an important factor in competitive ability of plants and hence, the structure of vegetation (Nilson et al. 1991). The present study indicated that *C. procera* thrives during the period from August to January and it reached its maximum stem diameter and volume in November. The

height and diameter records of an individual are particularly important because they reveal the maximum size attained by functionally different species' groups, which are crucial to a variety of ecological and evolutionary hypotheses (Niklas et al. 2006). Moreover, size variables had the lowest values during winter and early spring, which is characterized by low air temperature. According to Sharma and Amritphale (2007), the increase in temperature leads to increase in growth rate of plants and hence to the plant size, if adequate moisture is available.

The height/diameter ratio gives an idea about the growth habit of the plant. This ratio was more than unity for *C. procera* individuals all the year around that means the individuals tend to expand vertically rather than horizontally. In Nile Delta, Eid (2002) reported similar conclusions on *Ipomoea carnea*; Slima (2006) on *Pluchea dioscorides*; and also Galal (2011) on *Tamarix nilotica* in Wadi Gimal (Red Sea). On the contrary, many woody species in some hyper-arid regions showed ratio less than unity, which may be a strategy of the desert plants to provide safe sight for their self regeneration, as the horizontal expansion usually provides shade that leads to decrease the severe heating effect and increase the soil moisture (Shaltout et al. 2003).

Large individuals are more likely to continue to be alive and produce offspring than small ones (Eid 2002). Plant population structure such as the distribution of plant size and reproductive efforts has important evolutionary and conservation implications. With respect to the monthly size distribution, *C. procera* size fluctuated between three distribution patterns as mentioned above. Inverse J-shaped or positively skewed size distribution may represent rapidly growing populations with high reproductive capacity. Such

Fig. 2 Monthly size-frequency distribution of *Calotropis procera*. The different size classes are coded as follows: 1 <0.5 m, 2 0.5–1 m, 3 1–1.5 m, 4 1.5–2.5 m, 5 2.5–3.5 m, 6 >3.5 m



distributions may also indicate a high juvenile mortality (Damgaard and Weiner 2000; Gracia 2006). This result coincided with that of Shaltout and El-Beheiry (2000) on *Bassia indica* and El-Beheiry and Shaltout (2011) on *Cornulaca monocantha* population in Egypt. It seems that the *C. procera* have persistence strategy under urban habitat conditions. The positively skewed size distribution is indicative of a self-perpetuating species, with markedly more frequency of the smaller (younger) size classes

(Shaltout and Ayyad 1988; Weiner and Damgaard 2006). In addition, these distribution patterns are caused, through variations in growth rate, by factors such as: competition, heterogeneity of resources, genetic variation and small differences in the rate of emergence (Weiner and Solbrig 1984).

Bimodal size distribution was recorded for the species from November to January. This size distribution may result from initially unimodal size distribution when there

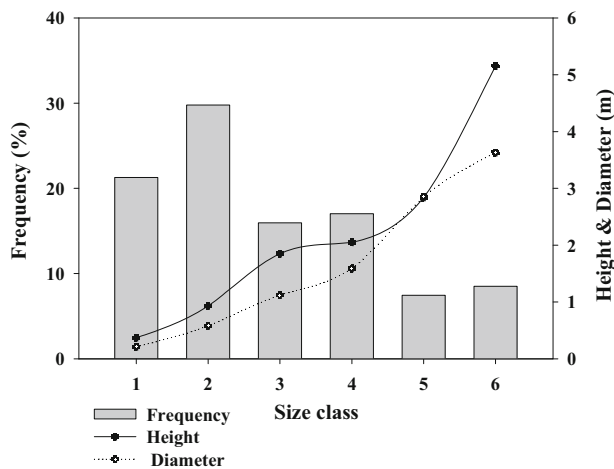


Fig. 3 Annual average of the size-class frequency distribution of *Calotropis procera*. The size classes are: 1 <0.5 m, 2 0.5–1 m, 3 1–1.5 m, 4 1.5–2.5 m, 5 2.5–3.5 m, 6 >3.5 m

is a discontinuous variation in exponential growth rates among individuals (Al-Sodany 2003). Normally distributed variation in exponential growth rates will not produce bimodality. Sources of discontinuous variation may be genetic and/or environmental heterogeneity, or dominance and suppression competition. Such competition may be considered asymmetric because the resulting negative effects are experienced only the smaller plants (Huston 1986).

High natality is often a direct response to the soil nutrients, especially organic matter, which enhances natality (Eid

2002). In addition, it was considered as a direct response to high soil calcium and magnesium content, where the two cations play an important role in the structural and enzymatic functions in the plant cell. On the other hand, it was found that *C. procera* had the maximum plant survival during June in roadsides that have high soil moisture content. According to Dalgleish et al. (2011), the lack of soil water could reduce a plant’s stored resources, and decrease its chance of survival or potential for growth. However, the high mortality rate in July with lower plant density may be attributed to water shortage rather than competition.

The relative change in the growth rate of *C. procera* population was measured on the basis of their demographic flux (Fr.). The demographic flux indicated that the new individuals of the plant were mainly formed during April and June, followed by significant mortality in July and October (Fr. = –1). This is an indication for higher mortality among the populations of the species than its natality. The maximum flux ratio of *C. procera* was recorded during spring; while the minimum was in winter. Conversely, Shaltout and El-Beheiry (2000) recorded the maximum and minimum flux ratios of *B. indica* in winter and spring, respectively. However, the annual average of demographic flux approximated zero indicating the equality of mortality and natality. This may be an indication for the stability of *C. procera* populations. According to El-Keblawy et al. (1997), species that have population growth rates close to unity tend to be perennial herbs or trees mainly inhabiting stable environments. While species with variable growth

Table 3 Monthly variations in the branch demography of *Calotropis procera*

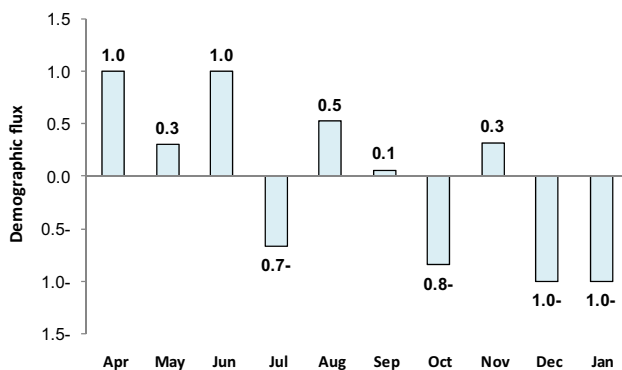
Months	Branch demography				Survival (%)	Total branches
	Living		Dead			
	Number	%	Number	%		
February	–	–	–	–	–	16.4 ± 28.6
March	3.5 ± 8.4	21.5	0.7 ± 2.3	4.1	95.7	19.2 ± 15.4
April	4.0 ± 10.5	24.4	1.2 ± 3.2	7.0	94.3	22.1 ± 17.3
May	2.9 ± 8.7	17.3	5.1 ± 13.5	31.2	76.5	19.8 ± 12.9
June	2.4 ± 6.6	14.4	2.3 ± 5.2	14.0	87.9	19.8 ± 11.9
July	2.9 ± 7.4	17.5	2.4 ± 5.4	14.7	87.9	20.3 ± 12.7
August	3.9 ± 9.0	23.6	3.5 ± 10.7	21.4	82.8	20.7 ± 15.0
September	5.0 ± 9.2	30.5	2.7 ± 5.9	16.2	87.0	23.0 ± 19.4
October	2.9 ± 5.2	17.5	4.6 ± 8.6	27.9	80.0	21.3 ± 19.9
November	4.4 ± 8.6	27.0	2.3 ± 4.8	14.0	89.2	23.4 ± 23.2
December	2.5 ± 5.0	15.4	3.3 ± 7.0	20.3	85.9	22.6 ± 22.8
January	4.4 ± 8.0	26.9	1.6 ± 3.1	9.5	93.4	25.5 ± 25.9
Average	3.5 ± 0.9		2.7 ± 1.4			21.2 ± 18.7

Minimum and maximum values are italics

Table 4 Monthly variations in the plant demography of *Calotropis procera*

Month	Plant Demography		Survival (%)
	Nativity (%)	Mortality (%)	
February	0	0	0
March	0	0	0
April	8.2	0	8.7
May	7.5	4	7.9
June	56.2	0	59.7
July	7.1	34.9	7.5
August	41.2	12.9	43.8
September	18.1	16	19.3
October	2.1	25.2	2.2
November	17.7	9.1	18.8
December	0	25.7	0
January	0	28.2	0
Average	13.2	13.0	13.9

Minimum and maximum values are italics

**Fig. 4** Monthly variation in demographic fluxes of *Calotropis procera* in the urban habitats, South Cairo

rates are short-lived herbs or shrubs growing mainly in disturbed and unstable environment.

5 Conclusion

The present study revealed that *C. procera* thrived well during the period from August to January, where it is characterized by the highest size variables, but it had the lowest values during the period from February to April. The plant does not produce any seeds during the period from December to March. The size structure of its populations showed stable persistence strategy under urban habitats conditions. High survival of the plant is depending on the soil moisture content. There was an obvious cycling in the natality and mortality of the plant. This plant exhibited no mortality during February, March, April and

June; while its maximum mortality (34.9 %) was in July; and its maximum natality (56.2 %) was in June.

References

- Abdel Hameed AA, Khoder MI, Yuosra S, Osman AM, Ghanem S (2009) Diurnal distribution of airborne bacteria and fungi in the atmosphere of Helwan area, Egypt. *Sci Total Environ* 407:6217–6222
- Allen SE (1989) Chemical analysis of ecological materials. Blackwell Scientific Publications, London
- Al-Sodany YM (2003) Size structure and dynamics of the common shrubs in Omayed Biosphere Reserve in the western Mediterranean coast of Egypt. *Ecol Med* 29:39–48
- Bekele T (2000) Plant population dynamics of *Dodonaea angustifolia* and *Olea europaea* ssp. *cuspidata* in dry Afromontane forests of Ethiopia. PhD Thesis, Acta Universitatis Upsaliensis, Sweden
- Crisp MD, Lange RT (1976) Age, structure, distribution and survival under grazing of the arid zone shrub *Acacia burkitti*. *Oikos* 27:86–92
- Dalgleish H, Koons D, Hooten M, Moffet C, Adler A (2011) Climate influences the demography of three dominant sagebrush steppe plants. *Ecology* 92(1):75–85
- Damgaard C, Weiner J (2000) Describing inequality in plant size or fecundity. *Ecology* 81(4):1139–1142
- Eid EM (2002) Population ecology of *Ipomoea carnea* Jacq. in the Nile Delta region. M.Sc. Thesis, Tanta University, Tanta
- El-Beheiry MA, Shaltout KH (2011) Demographic analysis of *Cornulaca monocantha* Delile population in Asir region, Saudi Arabia. *Egypt J Exp Biol (Bot)* 7(1):67–78
- El-Keblawy A, Shaltout KH, Lovett-Doust J, Ramadan A (1997) Population dynamics of an Egyptian desert shrub, *Thymelaea hirsuta*. *Can J Bot* 75:2027–2037
- El-Midany M (2014) Population dynamics of *Calotropis procera* (Aiton) W.T. Aiton in Cairo Province. M.Sc. Thesis, Helwan University, Cairo
- Farahat E, Galal TM, El-Midany M, Hassan LM (2015) Effect of urban habitat heterogeneity on functional traits plasticity of the invasive species *Calotropis procera* (Aiton) W.T. Aiton. *Rend Fis Acc Lincei* 26:193–201
- Frosi G, Oliveira MT, Almeida-Cortez J, Santos MJ (2012) Ecophysiological performance of *Calotropis procera*: an exotic and evergreen species in Caatinga, Brazilian semi-arid. *Acta Physiol Plant* 35(2):335–344
- Galal TM (2011) Size structure and dynamics of some woody perennials along elevation gradient in Wadi Gimal, Red Sea coast of Egypt. *Flora* 206:638–645
- Gottlieb LD (1977) Genotypic similarity of large and small individuals in a natural population of the annual plant *Stephano meria exigua* ssp. *coronaria* (Compositae). *J Ecol* 65:127–134
- Gracia O (2006) Scale and spatial structure effects on tree size distributions: Implications for growth and yield modeling. *Can J For Res* 36(11):2983–2993
- Hara T (1988) Dynamics of size structure in plant populations. *Trends Ecol Evol* 3:129–132
- Hassan LM, Galal TM, Farahat E, El-Midany M (2015) The biology of *Calotropis procera* (Aiton) W.T. *Trees* 29(2):311–320
- Huston M (1986) Size bimodality in plant populations: an alternative hypothesis. *Ecology* 67:265–269
- Lottermoser BG (2011) Colonisation of the rehabilitated Mary Kathleen uranium mine site (Australia) by *Calotropis procera*: toxicity risk to grazing animals. *J Geochem Explor* 111:39–46

- Moore PD, Chapman SB (1986) Methods in plant ecology, 2nd edn. Blackwell Scientific Publications, Oxford, pp 1–59
- Niklas KJ, Cobbi ED, Marler T (2006) A comparison between the record height-to-stem diameter allometries of *Pachycaulis* and *Leptocaulis* species. *Ann Bot* 97:79–83
- Nilson C, Ekblad A, Gardfjell M, Calberg B (1991) Longterm effects of river regulation on river margin vegetation. *J Appl Ecol* 28:965–987
- Nobel SP, Franco CA (1989) Effect of nurse plants on the microhabitat and growth of cacti. *J Ecol* 77:870–886
- O'Connor TG (1994) Composition and population response of an African savanna grassland to rainfall and grazing. *J Appl Ecol* 31:155–171
- Parsons WT, Cuthbertson EG (2001) Noxious weeds of Australia, 2nd edn. Csiro Publishing, Melbourne, p 712
- Peter B (1980) The demography of leaves in a permanent pasture. Ph.D. Thesis, University Collage of North-Wales, Bangor
- Pugnaire FI, Puigdefábregas J, Haase P (1996) Facilitation between higher plant species in a semiarid environment. *Ecology* 77:1420–1426
- Purves DW, Lawd R (2002) Experimental derivation of functions relating growth of *Arabidopsis thaliana* to neighbour size and distance. *J Ecol* 90:882–894
- Schemske DW, Husband BC, Ruckelshaus MH (1994) Evaluating approaches to the conservation of rare and endangered plants. *Ecology* 75:584–606
- Shaltout KH, Ayyad MA (1988) Structure and standing crop of Egyptian *Thymelaea hirsuta* populations. *Vegetatio* 74(2–3):137–142
- Shaltout KH, El-Beheiry M (2000) Demography of *Bassia indica* in the Nile Delta region, Egypt. *Flora* 195:392–397
- Shaltout KH, Sheded MG, El-Kady HF, Al-Sodany YM (2003) Phytosociology and size structure of *Nitraria retusa* along the Egyptian Red Sea coast. *J Arid Environ* 53:331–345
- Sharma S, Amritphale D (2007) Effect of urbanization on the population density of aak weevil. *Curr Sci India* 93:1130–1134
- Slima DF (2006) Sociological behaviour and variability among *Pluchea dioscoridis* (L.) DC. populations in Nile Delta. M.Sc. Thesis, Menoufia University, Shebin El-Kom, Egypt
- SPSS (2006) SPSS base 15.0 User's guide. SPSS inc., Chicago, USA
- 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, Damgaard C (2006) Size-asymmetric competition and size-asymmetric growth in a spatially explicit zone-of-influence model of plant competition. *Ecol Res* 21:707–712
- Weiner J, Solbrig OT (1984) The meaning and measurement of size hierarchies in plant populations. *Oecologia* 61:334–336