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Population Demography of *Calotropis procera* (Ait.) R.Br. in Taif Region, Saudi Arabia

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THE PRESENT study aims at evaluating the state of *Calotropis procera* to adapt to different environmental conditions and identifying the patterns and sizes in terms of dimensions, size structure and density. Seventy five stands were selected in Taif region and its adjacent area to represent the environmental variations associated with the distribution of *C. procera*. The population structure of this species was evaluated in terms of size distribution. All dimensions of *C. procera* differed significantly along the altitude gradient, habitat and locations, except that of diameter which did not differ significantly along the altitude gradient and habitats. The altitude of 1300-1500m above sea level had the maximum values of height, size index, volume and height: diameter ratio, while the altitude of 1500-1700 had the minimum of height, diameter, and size index. Regarding habitat types, wadi beds had the maximum values of diameter, size index and volume, while depression spots had the maximum of height and height:diameter ratio. Sand flats had the minimum values of all population dimension. The density of *C. procera* differed significantly along altitude gradients. The total mean of size index-class frequency distributions of *C. procera* population approximated the positive inverse J-shape in the study area towards the relative preponderance of small individuals.

Keywords: Demography, High altitudes, Population ecology, Size structure.

Introduction

Saudi Arabia extends over an area of 2026213 sq. km, and occupies almost two-thirds of the Arabian Peninsula (16º-32º N and 35º-56º E). This area represents about 1.5% of the total land area, about 5% of Asia and about 5% of the area of the arid zones in the world (Abd El Rahman, 1986). The genus *Calotropis* consists of common weedy species which occur in arid ecosystems but have become naturalized in warm climates, where they grow commonly in disturbed areas (Tezara et al., 2011). *Calotropis procera* is a wasteland weed of world-wide distribution but most abundant in the sub-tropics and tropics, and is rare in cold countries (Singh et al., 1996). It prefers open habitats where there is little competition with other plants, since these conditions can be generated following heavy grazing by cattle and other livestock. It can become particularly abundant on badly degraded areas such as abandoned cultivation, sandy soils in areas of low rainfall (CAB International, 2005; Taghvaei et al., 2015). However, there is evidence that *C. procera* can invade land with good pasture cover (Csurhes, 2016), but it seems best adapted to areas that have sparse ground cover. Research is required to fully assess its recruitment success in competition with pasture.

Calotropis species are drought (Colombo et al., 2007) and salt tolerant (Khan et al., 2007). However, the mechanism behind their successful distribution across arid regions is not well understood (Tezara et al., 2011). Although *C. procera* is a drought resistant and salt tolerant

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species to a relatively high level, its distribution across the semi-arid and arid regions can be a major reason behind its degradation (Boutraa, 2010). It quickly becomes established as a weed along degraded roadsides, lagoon edges and in overgrazed native pastures through wind and animal dispersed seeds. It is often dominant in areas of abandoned cultivation especially sandy soils in areas of low rainfall and it is assumed to be an indicator of over-cultivation and overgrazing (Francis, 2002). It prefers disturbed sandy soils (Orwa et al., 2009). It also grows at altitude up to 1300m, with the mean annual rainfall at 300-400mm. It is not frost tolerant (CAB International, 2005). *C. procera* is native in nearly all countries of tropical and subtropical Asia and Africa (GRIN, 2008; Pusapati et al., 2012) and is widely naturalized in Australia and the Americas, including the multitude of small adjacent islands (CAB International 2005; PIER, 2008).

C. procera was widely used in traditional medicine due to the pharmacologically active compounds found in its parts (bark, roots, leaves) and especially the milky latex which exudates from broken leaves and stems (Boutraa, 2010; de Lima et al., 2011; Chaudhary et al., 2017). Because of these active chemical compounds, *C. procera* was used for treatment of a number of diseases, such as ulcers, tumors, leprosy, piles and diseases of the spleen, liver and abdomen (Kumar & Arya, 2006). On the other hand, ecological studies on *C. procera*, especially those dealing with its demographic growth, are few and far between. For instance, Al-Sodany et al. (2016) studied the floristic composition and plant communities associated with *Calotropis procera* in Taif region.

The present study aims at: (1) Evaluating the state of *Calotropis procera* to adapt to different environmental conditions in Taif region, Saudi Arabia, (2) Identifying the patterns and sizes of its natural forests in the study area in terms of dimensions, size structure and density and (3) Assessing the differences between various population characteristics.

Materials and Methods

Study area

Saudi Arabia extends over approximately 16º degrees of latitude, from 16º 22' at the borders with Yemen in the south to 32º 14' at the Jordanian border in the north, and between 34º 29'E and 55º 40` E. Longitude. (Fig. 1). Taif region is located in the central foothills of the western mountains at an altitude of up to 2500m above sea level.

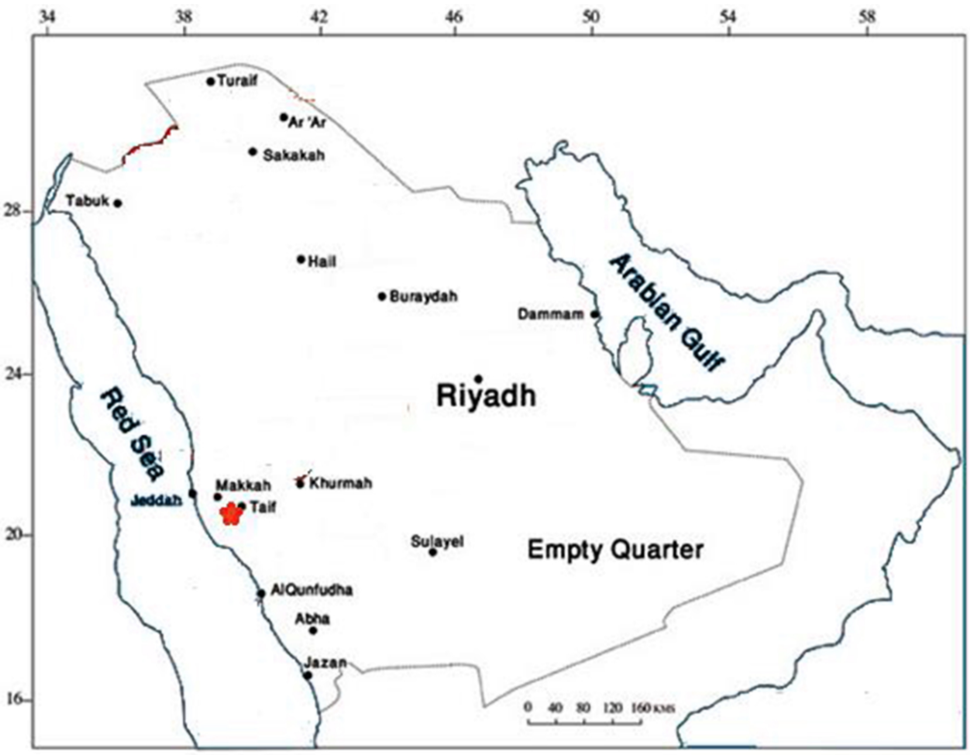

Fig. 1. Map showing the study area at Taif region (indicated by a star).

Climate of the area is tropical and arid. The monthly mean of climatic variables recoded in Taif meteorological station for 1997–2009 as recorded by Anonymous (2008) indicated that the monthly average of minimum and maximum ambient temperatures ranged from 7.9±1.2 to 23.4±0.8°C and 22.9±1.1 to 36.3±0.8°C, respectively with a total monthly mean of 23.2±5.1°C (Table 1). The mean maximum temperature (±SD) was between 2006 and 2008 was 36.33±1.15°C, while average values for the period between 1991 and 2005 were 33.60±3.03°C. During the same period, mean monthly humidity ranged from approximately 19.6±4.2 to 60.0±6.0%. The data for the last ten years shows considerable inter-annual variation in the monthly amount (range 4.3±5.7-294.1±383.8mm mo^{-1}) and timing of rainfall.

Sampling

Seventy five stands were selected in Taif region and its adjacent area to represent the environmental variations associated with the distribution of *Calotropis procera*. The stand size was about 20x20m (approximates the minimal area of the plant communities).

Demography and population structure

The population structure of *C. procera* was evaluated in terms of size distribution. For achieving this, the height (H) and mean crown diameter (D) of each of 1542 individuals in the whole stand were measured, based on 2-4 diameter measurements per individual and its volume was calculated as a cylinder according to the following equation: Volume= $\pi r^2 H$; where r is the radius and H is the height of the individual. The size index of each individual was calculated as the average of its height and diameter {(H+D)/2}. The size index estimates were then used to classify the population into 7 size classes: 1: <50, 2: 50-100, 3: 100-150, 4: 150-200, 5: 200-250, 6: 250-300, 7: >300cm. The first (<50cm) and the second (50-100cm) classes were chosen to represent the juvenile stage. The absolute and relative frequency of individuals in each size class were then determined (see Al-Sodany, 2003). Also, the mean height, diameter, size index, volume and height to diameter ratio in terms of: Habitat vs. altitude, habitat vs. size classes and altitude vs. size class for each species were assessed. The number of *C. procera* individuals in each stand were counted and then used to calculate its density in different habitats and altitudes.

TABLE 1. Monthly variation in air temperature (°C), relative humidity (% (RH), wind speed (WS) in km hr^{-1}) and rainfall (RF) (in mm $month^{-1}$, as recorded at Taif meteorological station.

Month	Temperature (°C)			RH (%)	WS (km hr^{-1})	RF (mm mo^{-1})
	Max.	Min.	Mean			
Jan.	22.9±1.1	7.9±1.2	15.4±1.0	58.7±5.6	5.5±0.5	12.1±12.0
Feb.	25.8±1.3	10.1±1.4	17.9±1.1	52.2±4.7	6.7±0.6	283.0±392.2
Mar.	27.5±0.9	12.0±1.2	19.8±0.7	46.5±7.1	7.2±0.9	22.5±23.7
Apr.	30.8±1.0	15.3±0.9	23.0±0.7	43.2±4.5	6.7±0.6	93.5±227.8
May	34.1±1.2	18.4±0.7	26.3±1.2	33.1±7.4	6.2±0.8	97.9±227.9
Jun.	36.3±0.8	22.2±0.9	29.4±0.6	19.6±4.2	8.3±0.6	141.8±314.4
Jul.	35.6±1.0	23.2±0.9	29.1±0.9	21.8±4.6	10.6±1.2	73.7±233.5
Aug.	36.3±0.5	23.4±0.8	29.5±0.4	27.5±4.4	9.7±0.9	92.8±229.2
Sep.	35.3±0.6	20.3±0.9	28.0±0.4	29.6±4.1	6.2±0.4	294.1±383.8
Oct.	31.2±0.7	15.3±0.6	23.5±0.6	39.7±7.9	5.0±0.4	88.0±231.8
Nov.	27.2±1.0	12.0±1.1	19.6±0.5	55.5±8.4	5.1±0.3	155.6±308.1
Dec.	24.4±1.4	9.3±1.0	16.7±1.1	60.0±6.0	5.1±0.7	4.3±5.7
Total mean	**30.6±4.8**	**15.8±5.5**	**23.2±5.1**	**40.6±14.8**	**6.9±1.9**	**113.3±257.4**
F-value	**270.2*** **	**348.3*** **	**457.5*** **	**63.8*** **	**73.1*** **	**1.5**

The data are long term averages from Climatological Normals for KSA, 1997–2007 (Anonymous, 2008). The F-value for each variable is calculated by (ANOVA), ***: P≤0.001.

Habitat types

Seventy five stands were selected to represent the different altitudes and the main habitats in the study area. Five main habitats were recognized in the study area which are associated with the distribution of *C. procera*: depression spots (DS), high altitudes (HA), mountain slopes (MS), sand flats (SF) and wadi beds (WB). They ate distributed along different altitudes as follows: 1- Altitudes less than 1300m above sea level include wadi beds (23 stands), mountain slopes (5 stands) and sand flats (9 stands); 2- Altitudes with 1300-1500m a.s.l. include depression spots (10 stands); 3- Altitudes with 1500-1700m a.s.l. include wadi beds (10 stands) and sand flats (8 stands) and 4- Altitudes more than 1700m a.s.l. include high altitudes (10 stands).

Soil analysis

Soil samples were collected from each stand as a profile (composite samples) at a depth of 0-50cm below the soil surface. The soil samples were brought to the laboratory in plastic bags shortly after collection, spread over sheets of paper, air dried, passed through 2mm sieve to remove gravel and debris, then packed in paper bags ready for physical and chemical analysis. Total organic matter was estimated based by loss-on-ignition at 450˚C. Soil water extracts at 1:5 were prepared for determination of soil salinity (EC), soil reaction (pH), chlorides, carbonates and bicarbonates. Soil reaction (pH) was estimated using a glass electrode pH-meter. Salinity was evaluated by a direct indicating conductivity bridge (mmhos/cm). Chlorides were estimated by direct titration against silver nitrate using 5% potassium chromate as indicator. Carbonates and bicarbonates were evaluated by direct titration against 1N HCl using phenolphthalein and methyl orange as indicators (Allen et al. 1989).

Statistical analysis

Means, standard deviations (SD) and Two-way analysis of variance (ANOVA-2) were calculated for the means of the respective height, crown diameter, size index, volume, H/D ratio and density in relation to locations, altitudes and size classes variables to assess the heterogeneity of samples around their means. Relationships between soil and population variables of *C. procera* were tested using Pearson's simple linear correlation coefficient (r). These techniques were according to SPSS software (SPSS 2011).

Results

The height, size index, volume and height/diameter ratio of *C. procera* differed significantly along the altitude gradient (F= 25.69, 8.2, 8.4 and 47.6, P<0.001). Generally, the height: diameter ratio (H/D) of *C. procera* is more than unit (Table 2). The height, crown diameter and size index of this species had the minimum value at altitude of 1500-1700 m a.s.l. (136.5±122.5, 119.3±136.1 and 127.9±127.2cm, respectively), while the volume had the lowest value at altitude of <1300 m a.s.l. (4.3±6.3m^3) and the height/diameter ratio at altitude of >1700m a.s.l. (1.31±0.56m^3). On the other hand, the height, size index, volume and height/diameter ratio of *C. procera* had the highest value at altitude of 1300-1500m a.s.l. 198.0±99.1, 160.5±91.1cm, 9.3±29.0m^3 and 2.17±1.37 with a total mean of 168.0±101.4, 146.4±97.4cm, 6.0±17.0m^3 and 1.66±0.88, respectively. The maximum crown diameter of this species was 138.7±102.0cm at altitude of >1700m a.s.l. with a total mean of 124.8±99.3cm (Table 2).

Regarding altitude vs. habitat, the height, size index and height/diameter ratio of *Calotropis procera* differed significantly in relation to altitude and habitat, but the crown diameter differed significantly in relation to habitat only and the volume differed significantly in relation to altitude, habitat and interaction between them (Table 2). The depression spots habitat had the highest values of height and height/diameter ratio at altitude of 1300-1500m a.s.l. (198.0±99.1cm and 2.17±1.37, respectively). The wadi beds habitat had the highest value of crown diameter at altitude of 1300-1500m a.s.l. (141.8±162.4cm), size index value at altitude of <1300m a.s.l. (161.6±75.4cm) and volume at altitude of 1500-1700m a.s.l. (14.6±38.5m^3). Sand flats habitat had the lowest values of height, crown diameter and size index value at altitude of 1500-1700m a.s.l. (120.7±91.2, 98.2±101.7 and 109.5±94.2cm, respectively) and volume at altitude of <1300m a.s.l. (2.8±5.4m^3), while the high altitudes habitat had the lowest height/diameter ratio at altitude of >1700m a.s.l. (1.31±0.56).

In the altitude vs. size class variations, the height, crown diameter, size index, volume and height/diameter ratio of this species had a significant difference in altitude, size class and interaction between them (Table 3). The altitude of 1500-1700m a.s.l had the maximum of height, size index and volume 416.1± 81.1, 425± 94.1cm and 71.6± 59.1m³, respectively. The maximum height/diameter ratio was 3.3±2.2 at altitude of 1300-1500m above sea level. On the other hand, the altitude of 1300-1500m a.s.l. had the minimum crown diameter, size index and volume (12.3±6.5, 24.7±12.0cm and 0.01±0.01m³, respectively), while the altitude of 1500-1700m a.s.l had the minimum height and height/diameter (32.5±17.2cm and 1.0±0.23).

As indicated in Table 4, the soils of altitude 1500-1700m a.s.l. have the highest values of all estimated soil variables: pH (7.74±0.11), salinity (314.96±477.14µmhos/cm), chlorides (0.03±0.05%) and organic carbon (3.29±0.93%), organic matter (5.67±1.60%) and bicarbonate (0.06±0.01%). The altitude of <1300a.s.l. has the lowest values of organic carbon (0.66±0.23%), organic matter (1.14±0.39%) and bicarbonate (0.03±0.01%). High altitudes (>1700m a.s.l.) have the lowest of pH (7.33±0.17) and salinity (42.49±5.90µmhos/cm). On the other hand, the depression spot habitat has the highest values of all estimated soil variables: pH (7.74±0.11), salinity (314.96±477.14µmhos/cm), chlorides (0.03±0.05%), and organic carbon (3.29±0.93%), organic matter (5.67±1.60%) and bicarbonate (0.06±0.01%). The high altitudes (>1700m a.s.l.) have the lowest pH (7.33±0.17), salinity (42.49±5.90µmhos/cm) and bicarbonate (0.03±0.00%), while the sand flats habitat has the lowest of chlorides (0.01±0.00%) and organic carbon (0.69±0.28%) and organic matter (1.20±0.48%).

TABLE 2. Mean±standard deviations of the dimensions in relation to altitudes vs habitats of *Calotropis procera* in the Taif region.

Altitude (m)	Habitat	No. of individuals	Height (cm)	Density (cm)	Size index (cm)	Volume (m³)	Height/ density
<1300	WB	554	185.1±81.1	138.1±74.5	161.6±75.4	4.8±6.5	1.53±0.66
	MS	118	150.1±88.2	102.6±73.1	126.4±78.8	3.1±5.9	1.67±0.68
	SF	112	146.1±74.7	107.2±74.6	126.7±70.2	2.8±5.4	1.61±0.59
	Total	784	174.3±83.0	128.3±75.7	151.3±76.8	4.3±6.3	1.56±0.65
1300-1500	DS	303	198.0±99.1	123.1±88.9	160.5±91.1	5.6±10.7	2.17±1.37
1500-1700	WB	214	153.4±147.2	141.8±162.4	147.6±152.7	14.6±38.5	1.38±0.55
	SF	228	120.7±91.2	98.2±101.7	109.5±94.2	4.3±13.6	1.60±0.72
	Total	442	136.5±122.5	119.3±136.1	127.9±127.2	9.3±29.0	1.49±0.65
>1700	HA	13	162.9±104.8	138.7±102.0	150.8±101.0	6.4±11.5	1.31±0.56
Total	WB	768	176.3±104.7	139.1±106.4	157.7±103.0	7.6±21.5	1.49±0.63
	MS	118	150.1±88.2	102.6±73.1	126.4±78.8	3.1±5.9	1.67±0.68
	SF	340	129.1±86.8	101.2±93.6	115.1±87.3	3.8±11.5	1.60±0.68
	DS	303	198.0±99.1	123.1±88.9	160.5±91.1	5.6±10.7	2.17±1.37
	HA	13	162.9±104.8	138.7±102.0	150.8±101.0	6.4±11.5	1.31±0.56
Total		**1542**	**168.0±101.4**	**124.8±99.3**	**146.4±97.4**	**6.0±17.0**	**1.66±0.88**
F-value		**Altitude**	**25.69*** **	**0.92**	**8.42*** **	**8.69*** **	**47.77*** **
		Habitat	**17.61*** **	**19.83*** **	**19.71*** **	**15.88*** **	**4.29** **
		Altitude* habitat	**0.21**	**0.84**	**0.06**	**12.38*** **	**1.37**

DS= Depression spots, HA= High altitudes, MS= Mountain slopes, SF= Sand flats, WB= Wadi beds.

TABLE 3. Mean±standard deviations of the dimensions in relation to altitudes vs size classes of *C. procera* in Taif region.

Altitude (m)	Class	No. of individuals	Height (cm)	Diameter (cm)	Size index (cm)	Volume (m^3)	Height/ diameter
<1300	<50	81	41.5±18.2	22.1±11.5	31.8±13.3	0.02±0.02	2.08±0.88
	50-100	126	96.2±20.9	56.7±15.9	76.5±14.1	0.3±0.2	1.85±0.89
	100-150	192	153.7±21.8	100.6±22.8	127.1±13.9	1.3±0.5	1.64±0.63
	150-200	198	197.6±20.2	147.9±24.9	172.7±14.2	3.5±1.1	1.39±0.34
	200-250	106	245.4±30.7	199.1±24.0	222.3±14.8	7.6±1.7	1.26±0.27
	250-300	45	299.5±48.1	246.6±43.1	273.1±16.4	14.0±3.2	1.26±0.33
	>300	36	361.8±36.7	302.6±37.3	332.2±26.1	26.4±7.5	1.21±0.20
	Total	784	174.3±83.0	128.3±75.7	151.3±76.8	4.3±6.3	1.56±0.65
1300-1500	<50	34	37.1±18.8	12.3±6.6	24.7±12.0	0.0±0.0	3.23±1.43
	50-100	36	109.3±25.1	43.7±19.3	76.5±15.1	0.2±0.2	3.33±2.28
	100-150	85	173.0±26.4	83.7±24.6	128.4±14.2	1.0±0.5	2.38±1.27
	150-200	64	213.6±26.0	132.8±25.0	173.2±15.3	3.0±1.1	1.68±0.47
	200-250	40	259.9±36.2	182.0±32.1	220.9±13.4	6.7±1.9	1.51±0.50
	250-300	22	315.2±31.0	231.5±36.7	273.4±14.1	13.3±3.5	1.41±0.36
	>300	22	413.1±52.2	332.5±56.9	372.8±49.7	37.8±16.0	1.26±0.19
	Total	303	198.0±99.1	123.1±88.9	160.5±91.1	5.6±10.7	2.17±1.37
1500-1700	<50	146	32.5±17.3	19.1±8.9	25.8±12.0	0.0±0.0	1.75±0.74
	50-100	100	84.7±18.0	54.2±16.7	69.5±12.4	0.2±0.1	1.71±0.69
	100-150	64	146.4±21.9	109.5±23.3	128.0±14.0	1.4±0.6	1.42±0.48
	150-200	41	185.9±25.2	164.5±24.8	175.2±15.2	4.0±1.2	1.16±0.26
	200-250	31	225.5±33.5	220.3±35.1	222.9±13.9	8.5±2.1	1.07±0.32
	250-300	13	276.3±45.7	273.0±42.3	274.7±13.3	15.9±3.0	1.05±0.31
	>300	47	416.1±81.1	434.0±128.6	425.0±94.1	71.6±59.1	1.01±0.24
	Total	442	136.5±122.5	119.3±136.1	127.9±127.2	9.3±29.0	1.49±0.65
>1700	<50	2	38.5±4.9	36.0±16.5	37.3±10.7	0.0±0.0	1.16±0.39
	50-100	3	105.0±36.2	69.6±21.1	87.3±16.8	0.4±0.2	1.66±0.98
	100-150	2	131.0±38.2	98.0±33.5	114.5±2.4	0.9±0.4	1.49±0.90
	150-200	4	185.3±25.2	163.5±24.5	174.4±13.5	3.9±1.1	1.16±0.28
	>300	2	361.5±43.1	336.3±37.7	348.9±2.7	31.9±3.3	1.09±0.25
	Total	13	162.9±104.8	138.7±102.0	150.8±101.0	6.4±11.5	1.31±0.56
Total	<50	263	35.9±18.1	19.2±10.0	27.6±12.7	0.0±0.0	2.04±1.02
	50-100	265	93.7±22.2	54.2±17.3	73.9±14.1	0.2±0.2	2.00±1.24
	100-150	343	157.0±25.0	98.1±24.9	127.5±14.0	1.2±0.5	1.78±0.89
	150-200	307	199.2±23.7	147.2±26.5	173.2±14.5	3.4±1.2	1.41±0.39
	200-250	177	245.2±34.1	198.9±30.4	222.1±14.3	7.6±1.9	1.28±0.37
	250-300	80	300.1±44.9	246.8±42.9	273.4±15.2	14.1±3.3	1.27±0.35
	>300	107	396.2±67.2	367.1±109.3	381.6±79.1	48.7±44.9	1.13±0.24
Total		**1542**	**168.0±101.4**	**124.8±99.3**	**146.4±97.4**	**6.0±17.0**	**1.66±0.88**
F-value		**Alt**	**296.61*** **	**8028*** **	**154.17*** **	**21.49*** **	**60.96*** **
		Class	**2749.63*** **	**2066.00*** **	**4493.29*** **	**337.27*** **	**59.89*** **
		Alt*Class	**7.44*** **	**19.71*** **	**22.41*** **	**22.88*** **	**5.99*** **

TABLE 4. Mean±standard deviation of soil characters in relation to altitudes and habitat of *Calotropis procera* population in Taif region.

		pH	EC	Cl (%)	OC (%)	OM (%)	HCO_3
Altitudes	<1300	7.54±0.20	71.18±39.76	0.01±0.00	0.66±0.23	1.14±0.39	0.03±0.01
	1300-1500	7.55±0.15	94.78±57.92	0.01±0.00	1.84±2.17	3.17±3.75	0.04±0.01
	1500-1700	7.74±0.11	314.96±477.14	0.03±0.05	3.29±0.93	5.67±1.60	0.06±0.01
	>1700	7.33±0.17	42.49±5.90	0.01±0.00	1.42±0.30	2.45±0.52	0.03±0.00
Total mean		**7.55±0.20**	**118.53±225.10**	**0.01±0.02**	**1.54±1.49**	**2.65±2.57**	**0.04±0.01**
F-value		**11.63*** **	**5.26** **	**4.71** **	**17.62*** **	**17.62*** **	**47.6*** **
Habitat	Wadi beds	7.53±0.19	85.62±57.87	0.01±0.00	1.28±1.70	2.21±2.93	0.03±0.01
	Mountain Slopes	7.57±0.06	65.50±7.64	0.01±0.00	0.74±0.39	1.28±0.67	0.04±0.01
	Sand flats	7.59±0.20	69.39±16.21	0.01±0.00	0.69±0.28	1.20±0.48	0.04±0.01
	Depression spot	7.74±0.11	314.96±477.14	0.03±0.05	3.29±0.93	5.67±1.60	0.06±0.01
	High altitude	7.33±0.17	42.49±5.90	0.01±0.00	1.42±0.30	2.45±0.52	0.03±0.00
Total mean		**7.55±0.20**	**118.53±225.10**	**0.01±0.02**	**1.54±1.49**	**2.65±2.57**	**0.04±0.01**
F-value		**9.13*** **	**3.9** **	**3.5***	**9.51*** **	**9.51*** **	**33.1*** **

*: P<0.05, **: P<0.01, ***: P<0.001. Cl= Chlorides, EC= Electrical conductivity, HCO_3= Bicarbonates, OC= Organic carbon, OM= Organic matter, pH= Soil reaction.

The pairs of soil and population variables that had highly significant (P<0.001) positive correlation are (Table 5): (i) Height:diameter ratio with pH, EC, chlorides, organic carbon, organic matter and bicarbonates (r= 0.298, 0.379, 0.418, 0.328, 0.328 and 0.475, respectively) and (ii) Density with pH, chlorides and bicarbonates (r= 0.357, 0.228 and 0.502, respectively). The pairs of population variables that had highly significant (P<0.001) positive correlation are: (i) Height with crown diameter, size index and volume (r= 0.867, 0.966 and 0.644, respectively) and (ii) Crown diameter with size index, volume and height:diameter ratio (r= 0.966, 0.829 and 0.430, respectively). The density had highly significant (P<0.001) negative correlation axis 1, height, crown diameter, size index, volume and height: diameter ratio (r= -0.483, -0.229, -0.372, -0.311, and -0.258, respectively).

The total mean of size index-class frequency distributions of *C. procera* population approximated the positive inverse J-shape in the study area towards the relative preponderance of small individuals (Fig. 2, 3). On average, the first three size index-classes contributed 56.5% of the total individuals compared with 23.6% of the last three classes. The moderate individuals (middle class) contributed 19.9% of all individuals. On the other hand, the first three classes (juvenile) had the highest contribution in the sand flats habitat (79.1%) and the lowest in the wadi beds habitat (49.3%). In contrast, the last three classes (old) had the highest contribution in the wadi beds habitat (28.0%) and the lowest in the sand flats habitat (9.6%) (Fig. 2). Regarding habitat types, the first three classes (juvenile) had the highest contribution at altitude 1500-1700a.s.l. (70.1%), while the lowest at altitude 1300-1500a.s.l. (51.2%). The last three classes (old) had the highest contribution at altitude 1300-1500a.s.l. (27.7%) and the lowest at high altitude of >1700a.s.l. (15.4%) (Fig. 3).

The size index-class frequency distributions of *C. procera* population along habitat types approximated the inverse J-shape towards the relative preponderance of the small individuals along mountain slopes and sand flats, positive skewed shape along wadi beds and depression spots and stationary shape along high altitudes (Fig. 2). Regarding the altitudes, it approximates the inverse J-shape towards the relative preponderance of the small individuals at altitude of 1500-1700m a.s.l.; positive skewed shape at altitudes of <1300m and 1300-1500m a.s.l.; and stationary shape along high altitude of >1700m a.s.l. (Fig. 3).

The density of *C. procera* differed significantly along the location and/or altitude gradients (F= 26.75, P<0.001). The maximum of the means of populations was at altitude of 1300-1500m in Riyadh Road (803.6±331.9ind. ha^{-1}), while the minimum mean was at high altitude of >1700m (32.5±12.1ind. ha^{-1}) (Fig. 4). On the other hand, the density of *C. procera* differed significantly along the habitat types (F= 19.78, P<0.001). The maximum of the means of populations was along depression spots (803.6±331.9ind. ha^{-1}), while the minimum mean was along high altitudes habitat (32.5±12.1ind. ha^{-1}) (Fig. 4).

TABLE 5. Pearson correlation coefficient (r-values) between soil and population variables of *Calotropis procera* in Taif region.

	Height (H)	Diameter (D)	Size index	Volume (H)	H:D ratio	Density
pH	0.113	-0.024	0.047	-0.004	0.298**	0.357**
EC	0.102	-0.015	0.045	0.030	0.379***	0.095
Cl	0.090	-0.073	0.009	-0.050	0.418***	0.228*
OC	0.019	-0.008	0.006	0.171	0.328**	0.227
OM	0.019	-0.008	0.006	0.171	0.328**	0.227
HCO_3	0.032	-0.154	-0.063	-0.088	0.475***	0.502***

Cl= Chlorides, EC= Electrical conductivity, HCO_3= Bicarbonates, OC= Organic carbon, OM= Organic matter, pH= Soil reaction. *= P<0.05, **= P<0.01, ***= P<0.001.

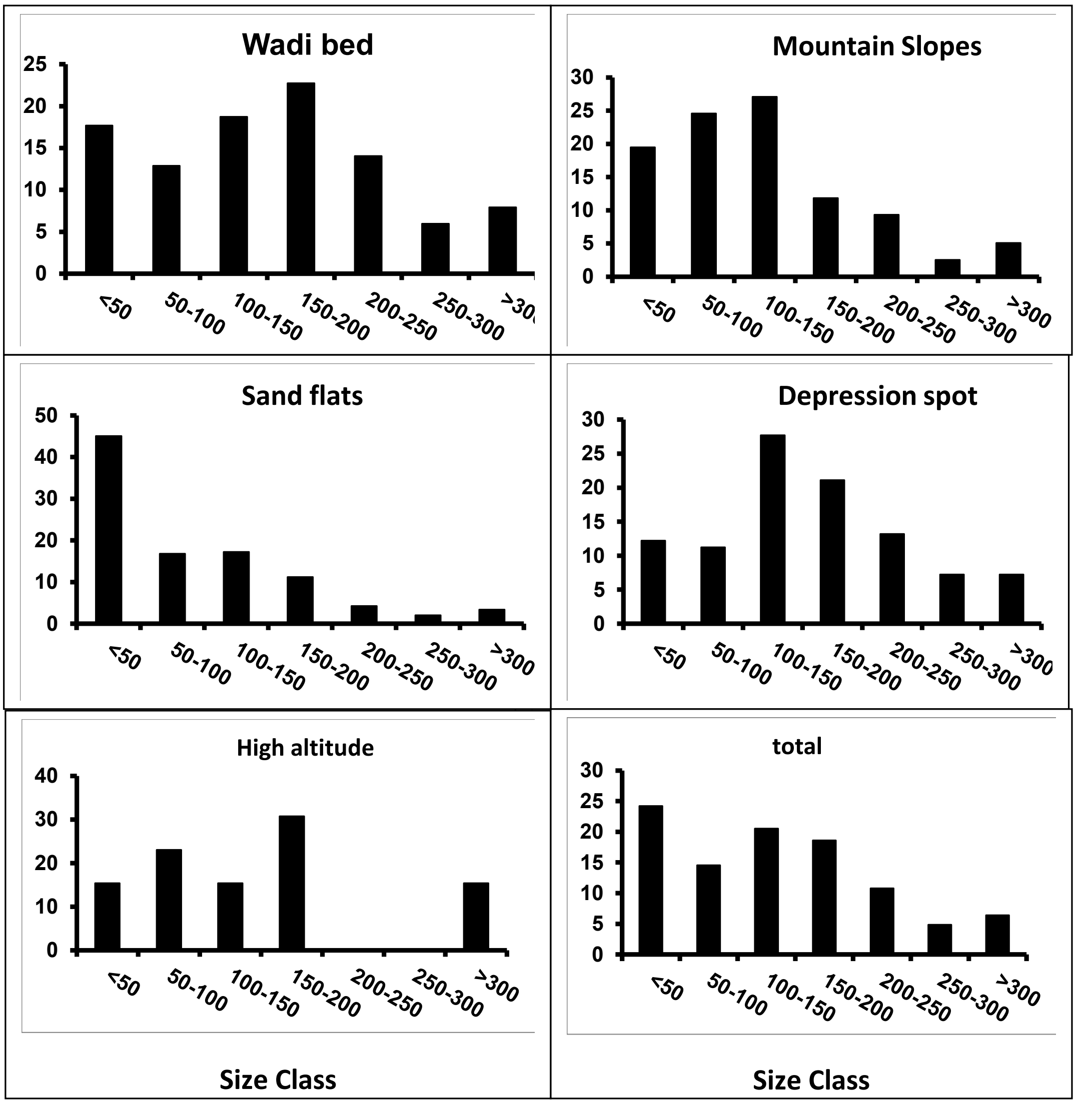

Fig. 2. Size index-class frequency of *Calotropis procera* population in different habitats.

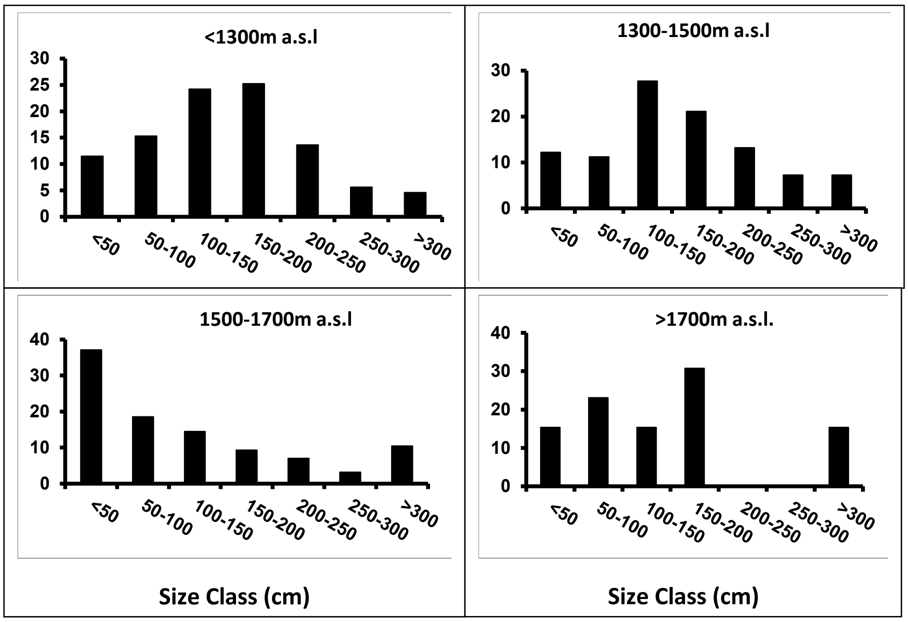

Fig. 3. Size index-class frequency of *Calotropis procera* population at different altitudes.

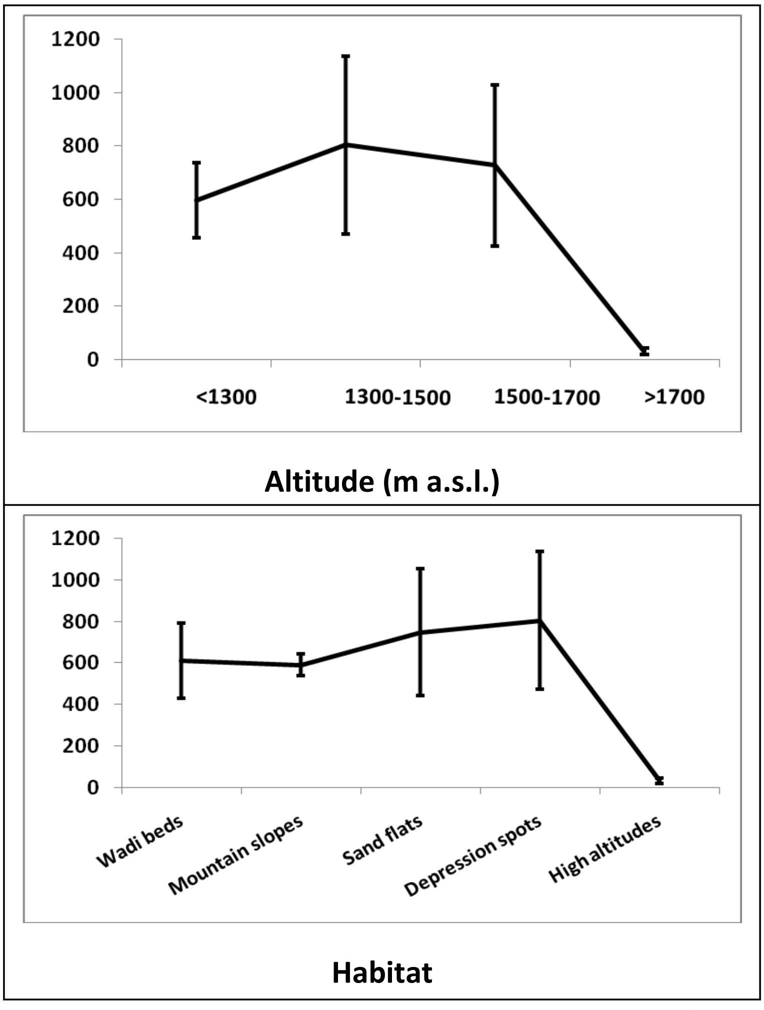

Fig. 4. Mean and standard deviation (vertical bars) in the individual density (ind. ha^{-1}) of *Calotropis procera* in Taif region.

Discussion

Demographic analyses are useful tools in the evaluation of the conservation status of plant species, since they provide basic information about the growth, survival and reproduction of individuals in different size and age classes within a population and determine a degree of species endangerment (Davy & Jeffries, 1981; Primack, 1995). Furthermore, the size/age structure of populations provides an indication of their regeneration process and their conservation status (de Kroon et al., 1986; Primack, 1995). Moreover, the structure of plant population can be assessed in terms of the ages, sizes and forms of the individuals that compose it (Lusk, 2003; Witt, 2004) and are functions of recruitment, growth, and mortality (Baker & Wilson, 2003), which were not differentiated by Kelly et al. (2001) or Kelly & Bowler (2002). The present study indicated that the size structure of *Calotropis procera* in Taif area in Saudi Arabia by size index can be used for determining the size classes of this species.

Since the fecundity and survival of plants is often more closely related to size than to age, some authors (e.g., Kirkpatrick, 1984) have argued that it is better to classify the plant life history by size rather than age. Size differences in plant populations may be caused directly or through differences in growth rates due to age difference, genetic variation, heterogeneity of resources, herbivory and competition (Harper, 1977; Winer, 1985). In the study area, *C. procera* showed three different size structures (inverse J-shape, positive skewed and stationary shapes) reflecting the differences in the nature of the habitat and the water availability. The populations of all habitats and altitudes had a comparable proportion of young and mature individuals except at high altitudes. This may indicate that recruitment is frequent due to the low altitude than high altitudes, as well as the abundance of the large limestone smooth-faced rock outcrops that are assumed as favorable sites, lowering the extinction rate of populations (Danin, 1978).

The inverse J-shape and positively skewed size distributions towards the small (i.e., young) individuals of *C. procera* in the study area mean that these may represent rapidly growing populations with relatively high reproductive capacity. Such distributions may indicate also a high juvenile mortality (Harper, 1977), but nevertheless, they seem to represent long-term stability, since in most stable populations one would except an excess of juvenile over mature individuals (Crisp & Lange, 1976; Goldberg & Turner, 1986; Shaltout & Ayyad, 1988). Moreover, this species produced a large number of seeds per year which are non-palatable in the study area. Furthermore, Gray (1975) reported that the positively skewed distribution is indicative of a self-perpetuating species, with markedly more frequency of the smaller (younger) size classes. Similar conclusion was made by Shaltout & Ayyad (1988) and Al-Yasi (2010).

On the other hand, the observation during the present study indicated that *Calotropis procera* had little growth at high altitudes and grows well in the urban habitats with high human impact. The fact that reduction in growth in high altitude of *C. procera* plants, could be due to the effects of severity of drought or the sensitivity of *C. procera* plants to wet conditions. Growth rates observed in plants grown under moderate water stress were nearly two-fold and three-fold higher than the growth rates of plants grown under severe water conditions and wet conditions, respectively (Boutraa, 2010). However, Altaf (2006) indicated that *Calotropis procera* can be a useful botanical monitor of pollution. The variations found in the concentrations of Br, Mn, Se, Cr and Zn between urban and suburban samples suggest that the plant has a good potential for the determination of these elements when it is exposed to them from any source. Br, Mn and Zn concentrations in the plant were found greater in the urban area than in controls which emphasizes the assumption that they are resulting from traffic pollution.

The present study suggested that this plant may naturalized in all habitats in the kingdom of Saudi Arabia and the vegetation of these habitats can be affected. This may be due to the fact that *Calotropis* has (a) A large number of small seeds capable of wind-dispersal and speedy germination-juvenile traits, (b) A strong competitive ability *(sensu* Chadwick and Obeid) and (c) A large size (see results) - adult traits. Shipley et al. (1989) argued that the concept of r-K strategists predisposes an association between juvenile and adult traits. In Grime's C-S-R ordination triangle of plant strategies (1974, 1977, 1979) this association between juvenile and adult traits is not found. Rather than conforming to a set type of life-history strategy, the results in the present investigation may describe *Calotropis* as (a) A perennial, (b)

A stress-tolerant ruderal (Grime, 1977) and (c) A weed.

In desert environments, the plant's reaction to the different sorts of stress might be worth studying for itself, as the mechanisms behind stress tolerance are not fully understood (Levitt, 1980). On the hand, the results of such studies are vital for extending the range of cultivation of economically important plants, such as the medicinal plant *C. procera*. Because no detailed studies on the ecology of *C. procera* have been conducted, a study of this type is needed to enhance the conservation efforts for this species (Boutraa, 2010). In contrast to crop plants, growth of desert plants under controlled conditions is less understood. For example, most studies on *Calotropis procera* are focusing on the pharmacological and medicinal aspects. Studies of this type are very limited. Due to the importance of *C. procera* in medicine, pharmacology and desert environment (Kumar & Arya, 2006; Boutraa, 2010; de Lima et al., 2011; Chaudhary et al., 2017), further studies on the effects of different climate conditions on growth performance and other physiological and biochemical aspects are encouraged. The climate conditions that need to be investigated might include drought, heat and salinity. Such studies will help in understanding the favourable growth conditions of this species for regeneration and to preserve soils with less plant cover in semi-arid and arid conditions, where the plant is subjected to deterioration by a number of means such as harsh growing conditions and grazing. The preliminary results presented in this study suggest that *C. procera* grows better under moderate water availability conditions due to human impact.

Conclusion

The present study indicated that the height, size index, volume and highet:diameter ratio of *Calotropis procera* differed significantly along the altitude gradient and locations and habitat types, while the crown diameter did not differ significantly along the altitude gradient and locations. The present study indicated that *Calotropis procera* grows well at low altitudes and decreases at high altitudes above 1700m above sea level.

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ديموجرافية جماعة نبات العشار في منطقة الطائف بالمملكة العربية السعودية

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تهدف الدراسة الحالية إلى تقييم حالة نبات العشار على التكيف في الظروف البيئية المختلفة، والتعرف على أنماط وأحجام جماعة نبات العشار من حيث الأبعاد والتركيب الحجمي والكثافة. تم اختيار خمسة وسبعون موقعا في منطقة الطائف والمناطق المجاورة لها لتمثل الإختلافات البيئية المصاحبة لتوزيع نبات العشار. وتم تقدير التركيب الحجمي للنبات من حيث التوزيع الحجمي. تختلف جميع أبعاد نبات العشار بدرجة ذات دلالة معنوية في كل من المواطن والإرتفاع فوق سطح البحر، وسجلت القيم القصوى لإرتفاع النبات، ومعامل الحجم، ونسبة الإرتفاع : القطر على إرتفاع 1300-1500م فوق مستوى سطح البحر، في حين أن الحد الأدنى لإرتفاع النبات، والقطر، ومعامل الحجم على إرتفاع 1500-1700م فوق مستوى سطح البحر. أما بشأن أنواع المواطن، فإن مواطن بطن الوادي أظهرت الحد الأقصى لقيم القطر، ومعامل الحجم، والحجم، في حين أظهر موطن البقع المنخفضة، الحد الأقصى من الطول ونسبة الإرتفاع : القطر. وأظهرت المسطحات الرملية القيم الدنيا من كل أبعاد جماعة نبات العشار. وقد أظهرت الكثافة اختلافات ذات دلالة معنوية في الإرتفاعات المختلفة فوق سطح البحر. يقترب تردد المتوسط الكلي لمعامل حجم التوزيعات لأفراد نبات العشار من الشكل معكوس الرائي في منطقة الدراسة نحو رجحان نسبي للأفراد الصغيرة.