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POPULATION ECOLOGY OF *CLEOME VISCOSA* L., A DESERT SUMMER ANNUAL

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Abstract

The present study was designed to investigate the demographic patterns of *Cleome viscosa* L., which is the common summer annual of Sindh desert. Demographic studies were carried out at two site named as site 'A' and site 'B'. Plants exhibited Deveey type I survivorship curves, characteristic of annuals. Populations of *C. viscosa* were found to be highly dynamic on spatial scale. Soil moisture content, competition and grazing were some of the factors responsible for the considerable variations in the plant density and growth of plants. Plants inhabiting site 'B; exhibited better vegetative and reproductive growth due to greater amounts of soil nutrients and high water holding capacity of the soil (thereby providing better soil moisture regime). *C. viscosa* at both the sites possessed persistent seed bank. The below ground seed bank was much diverse than the above ground vegetation. *C. viscosa* produced light weighted seeds in large numbers. Wind is the predominant agent for the dispersal of seeds. Seeds traveled grater distances mainly due to their lighter weights and taller mother plants.

Introduction

Summer annuals are the important components of the flora of arid and semi-arid regions. Seeds of annuals remain dormant in the soil for some period and germinate when moisture is available and temperature is suitable. Thus converting the whole desert visually into a grassland. Such annuals complete their life cycle within 3-4 months and exhibit a number of morphological, anatomical and physiological characteristics, which enable them to withstand xeric habitats. According to Astorga & Farfan (2000), emergence time of seedlings has great ecological and evolutionary significance in seasonal environments due to their relationship with fitness components.

Buried seed reserves also affect the dynamics of populations, they are usually present in all habitats and ensure the germination at suitable time of the year. While some seeds remain dormant in the soil for long duration. Leck & Schutz (2005), reported that seed bank development and their persistency in sedges (Cyperaceae), were associated with germination and dormancy traits. Temporal and spatial variation (Coffin & Lavenroth, 1989; Shaukat & Sidddiqui, 2004), soil heterogeneity (Boudell *et al*., 2002), disturbance varying in scale and frequency (Aziz & Khan, 1995; 1996) influence the position and composition of seeds within the soil profile. Knowledge of both the vegetation and soil seed bank of a community helps to understand species storage and regeneration potential (Mc Nicoll & Augspurger, 2010). Dispersal is the only way for the addition of seeds into the buried seed reserves. Plants usually rely upon different dispersal vectors for the dispersal of seeds away from the parent plant, which increases the probability to colonize new areas.

The purpose of this study have to determine the demographic pattern of *Cleome viscosa* and to evaluate the extent of seed bank and seed rain and their potential role in the development of *C. viscosa* populations on the ground.

Materials and Methods

Study site and the selected species: This study was conducted in Karachi, Sindh (Lat. 24^0 48 N., Long. 65^0 55 E.). This is a dry and semi-arid region, composed mainly of xerophytic vegetation. Mean temperature in the summer is 32^0 C, evapotranspiration is also high. Humidity is highest in the month of September. The precipitation occurs mainly in monsoon (June–September), with an average of 220 cm of rain per year.

Two sites were selected for the study. One of the study site is situated within Karachi University campus, called as site 'A' and the other near PCSIR (Pakistan Council of Science and Research Institute), named as site 'B'. Site 'A' is somewhat disturbed area, very much exposed to trampling and grazing. This site is located in a non-shady area, whereas, site 'B' is relatively a less disturbed site. It is situated in a shady area due to some larger trees in the study area. Moreover, the site is also surrounded by buildings. After monsoon rains, water from the adjacent elevated areas moves towards site 'B', thereby creating relatively better moisture regime than that of site 'A'.

Cleome viscosa L. (Capparidaceae), is a summer annuals, abundant or common in the waste grounds, vacant lots, road-sides and abandoned fields. *C. viscosa* is an ornamental plant and it is also important economically. Some species of the genus *Cleome* are valued for capers used in seasoning the food. It is found throughout the tropics. It is a common plant of Pakistan, India, Afghanistan, Arabia and North Africa.

Demography, biomass allocation and fecundity: Ten 1 m^2 permanent plots were established at random locations within each site for studying demography of *Cleome viscosa.* at two habitats named as site 'A' and site 'B'. Plots were censuzed every ten days throughout the growing season. Conventional life-tables and survivorship curves were constructed. A chi-squared test was performed to compare the survival rates at the two selected sites. At every sampling date, ten individuals were randomly collected from the outside of permanent plots. After measuring their size, their dry weights were recorded (80^0 C for 48 hr), and biomass allocation was determined. Fecundity (number of fruits per plant and number of seeds per fruit of the plants collected from the outside of permanent plot was also recorded.

Seed bank: Twenty soil samples were randomly with the help of aluminum corer (15 cm deep and 2.5 cm diameter) from both the sites. Soil samples were collected at three different phonological states i.e., before rainfall (before germination of seeds), after rainfall (after germination of seedlings) and after seed dispersal. Seeds were sorted out manually with the help of a binocular microscope, identified and counted.

Dispersal: At both the sites, ten isolated mature plants of *Ipomoea sindica* (prior to seed loss) were selected. Dispersal distance around each plant was studied by collecting seeds from 3.8 cm diameter, from 0-100 cm. Data was taken at alternate days with the initiation of dispersal. Seeds within 3.8 cm diameter area were converted to seeds per decimeter square (seeds / dm^2) and a dispersal curve was plotted between number of seeds / dm^2 and the distance traveled by seeds from the parent plant was calculated.

Soil moisture regime: Soil samples were collected at monthly intervals from July to October. After recording fresh weights, samples were then dried to a constant dry. Soil moisture was determined by using the following formula:

$$\text{Water content percent} = \frac{\text{Loss in weight on drying}}{\text{Weight of oven-dried soil}} \text{ X } 100$$

Results

Demography: The life table *Cleome viscosa* for site 'A' and 'B' showed that plants were observed to complete their entire life i.e., from germination to seed maturation in 12 weeks (Tables 1 & 2). Survivorship curves at both the sites followed Deevey type-I (Deevey, 1947), survivorship curve (Fig. 1). Plant density varied significantly ($p<0.001$) at each site. Site 'B' exhibited greater density and mortality of plants. Mortality rates were greater in the later stages of plant life. The results of chi-square and G test are presented in Table 3. Comparison of survivorship curves at both the sites using chi-square and G test exhibited significant differences at both the sites. Comparisons of curves showed significant differences at both the sites.

Table 1. Life table of *Cleome viscosa* individuals inhabiting site 'A.

Age (x) (weeks)	Numbers surviving (lx)	Numbers dying (dx)	Stationary Population (Lx)	Residual life-span (Tx)	Age specific mortality (qx)	Expectancy of further life (ex)
1	1000.00	51.86	974.07	5018.44	0.05	5.01
2	948.14	148.14	874.07	4044.37	0.15	4.26
3	800.00	133.34	733.33	3170.30	0.16	3.96
4	666.66	111.11	611.10	2436.97	0.16	3.65
5	555.55	37.04	537.03	1825.87	0.16	3.28
6	518.51	59.26	188.88	1288.84	0.11	2.48
7	459.25	111.11	403.69	799.96	0.24	1.74
8	348.14	200.00	248.14	396.27	0.57	1.13
9	148.14	81.84	107.40	148.13	0.55	0.99
10	66.66	59.29	37.03	40.73	0.88	0.01
11	7.40	7.40	3.70	3.70	1.00	0.50
12	-	-	-	-	-	-

Table 2. Life table of *Cleome viscosa* individuals inhabiting site 'B'.

Age (x) (weeks)	Numbers surviving (lx)	Numbers dying (dx)	Stationary Population (Lx)	Residual life-span (Tx)	Age specific mortality (qx)	Expectancy of further life (ex)
1	1000.00	33.34	983.33	5586.56	0.03	5.58
2	966.66	33.33	949.99	4603.23	0.03	4.76
3	933.33	313.33	776.66	3653.24	0.33	3.91
4	920.00	253.34	643.33	2476.58	0.27	3.12
5	666.66	33.33	649.99	2233.25	0.04	3.34
6	633.33	166.67	549.99	1583.26	0.26	2.49
7	466.66	120.00	406.66	1033.27	0.25	2.21
8	346.66	46.67	323.32	626.61	0.13	1.80
9	299.99	66.67	216.65	303.29	0..33	1.01
10	133.32	113.33	76.65	86.64	0.55	0.64
11	19.99	19.99	9.99	9.99	1.00	0.49
12	-	-	-	-	-	-

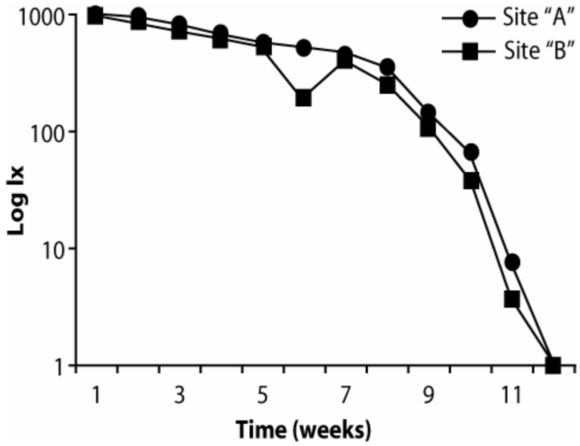

Fig. 1. Survivorship curves for *Cleome viscosa* individuals inhabiting site 'A' and'B'.

Table 3. Curve comparison of *Cleome viscosa* individuals at site 'A' and 'B', using chi-squared test.

Time period	χ2	Significance	G
0.25	32.45	0.001	40.78
0.03	30.51	0.001	35.27
2.27	43.76	0.001	47.95
5.07	47.80	0.001	50.42
10.60	11.89	0.001	11.99
4.13	3.86	0.05	3.88
5.44	5.80	0.05	5.83
8.71	0.23	n,s.	0.23
3.55	0.07	n.s.	0.07
6.47	7.96	0.01	8.42
Total	**184.38**	**0.001**	**204.87**

Growth and biomass allocation: Pattern of root and shoot growth for site 'A' and 'B' is illustrated in Fig. 2, showing a typical sigmoid curve, a characteristic feature of annuals. Site 'B' plants were taller as compared to site 'A' and exhibited significantly ($p<0.001$) greater growth rates. Total dry weight was also greater for site 'B' plants (Fig. 3) and showed significant differences with site (root, $F = 9.05$ $p<0.001$; stem, $F = 32.11$, $p<0.001$; leaf, $F = 373.33$, $p<0.001$). Relative growth rates (RGR) of the selected species showed decrease in the later stages of life (Table 4).

Allocation of percent biomass to component organs for both the sites is presented in Fig. 4. Plants allocated higher amounts of biomass to reproductive organs. Reproductive output was higher at site 'B'. Percent dry weight allocated to vegetative organs decreased with the onset of flowering. *C. viscosa* flowered at the age of about 50 days at site 'A' and about 45 days at site 'B'.

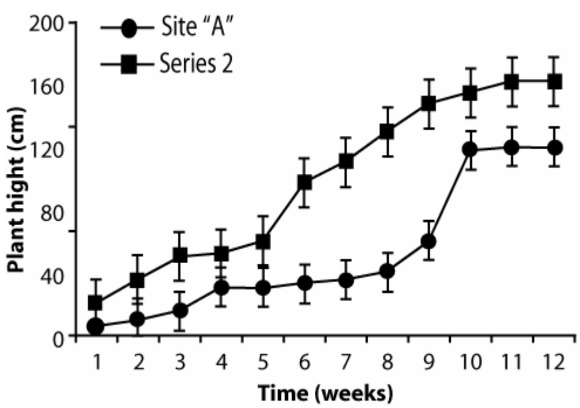

Fig. 2. Plant height (cm) of *Cleome viscosa* individuals inhabiting site 'A' and'B'.

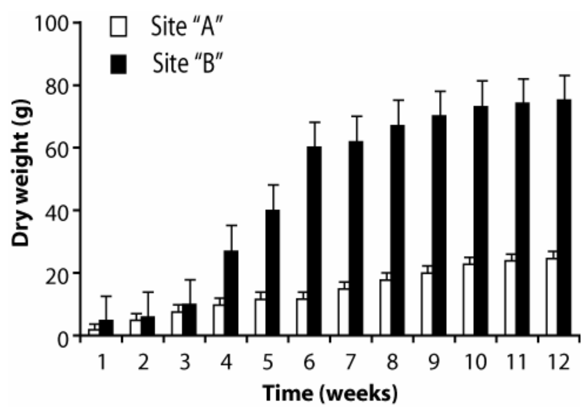

Fig. 3. The total dry weight (mg / plant) of *Cleome viscosa* individuals inhabiting site 'A' and'B'.

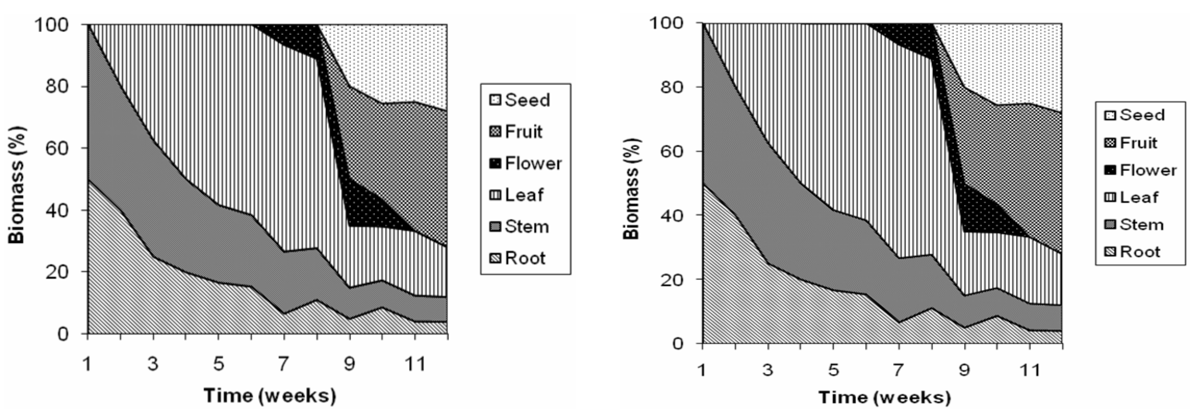

Fig. 4. Biomass allocation (%) of *Cleome viscosa*, to component organs at site 'A' and'B'.

Table 4. Relative growth rates (RGR) of *C. viscosa* at site 'A' and 'B'.

Time (weeks)	Site 'A'	Site 'B'
1	0.0100	0.024
2	0.009	0.014
3	0.010	0.012
4	0.004	0.0006
5	0.008	0.012
6	0.004	0.007
7	0.005	0.006
8	0.004	0.004
9	0.003	0.006
10	0.001	0.004
11	0.0002	0.0008
12	-	

Seed bank: Seeds of 6 species were collected from the samples of site 'A' and 10 from site 'B'. 6 out of 7 species were present in the existing vegetation at site 'A' and 8 out of 10 at site 'B' (Table 5). Site 'A' consist seeds of following species: *Cleome viscosa, Digera muricata, Tephrosia subtriflora, Chrysopogon aucheri, Tribulus terrestris and Gynandropsis gynandra*. *T. terrestris* was not present in the above ground vegetation.

Samples of site 'B' contained the seeds of the species viz., *Cleome viscosa, Digera muricata, Aristida mutabilis, Cleome brachycarpa, Rhyncosia minima, Zizyphus nummularia, Leucas urticifolia, Tephrosia subtriflora, Chrysopogon aucheri* and *prosopis Juliflora*. *A. mutabilis* and *T. subtriflora* were present only in the seed bank samples and not in the existing vegetation.

Significantly ($p<0.001$) higher number of seeds was sorted out in the third collection (after seed rain), followed by first collection (before rainfall / before germination). Lowest number of seeds was sorted out from the second collection (after germination of seeds).

C. viscosa exhibited significant differences with time ($F = 22771.12$, $p<0.001$) and site ($F = 16101.59$, $p<0.001$). whereas, interaction of time x site ($F = 3590.48$, $p<0.001$) also exhibited significant differences.

Table 5. Seeds /m2 extracted from the soil samples collected at three different phonological states at site 'A and site 'B'. (Mean ± Standard Error).

Plant species	Before rainfall		After rainfall		After dispersal	
	Site 'A'	Site 'B'	Site 'A'	Site 'B'	Site 'A'	Site 'B'
I. sindica	33506.33 ± 1.01	48946.00 ± 1.23	9699.20 ± 0.30	11462.69 ± 0.11	37033.31 ± 0.42	6436.42 ± 0.75
C.viscosa	61722.19 ± 0.32	152341.98 ± 0.23	17634.91 ± 0.20	26452.36 ± 0.36	90819.79 ± 0.54	148133.26 ± 0.66
D. muricata	44969.02 ± 1.15	69657.90 ± 0.32	1571.42 ± 0.25	20280.14 ± 0.35	53786.48 ± 0.55	73184.88 ± 0.56
T. subtriflora	2152.21 ± 0.50	4408.72 ± 0.37	-	2645.23 ± 0.22	4408.72 ± 0.51	5290.47 ± 0.32
C. aucheri	4408.72 ± 0.53	1763.49 ± 0.15	1763.49 ± 0.33	-	1763.49 ± 0.35	-
T. terresteris	-	-	-	-	2645.23 ± 0.11	-
G. gynandra	3526.98 ± 1.05	-	881.74 ± 0.14	-	6172.21 ± 0.41	-
C. brachycarpa	-	3526.98 ± 0.44	-	1763.49 ± 0.28	-	5290.47 ± 0.58
R. minima	-	4408.72 ±0.65	-	2645.23 ±0.34	-	5290.47 ± 0.39
L. urticifolia	-	4408.72 ± 0.58	-	881.74 ± 0.54	-	3526.98 ± 0.72
P. juliflora	-	1763.49 ± 0.35	-	1763.49 ± 0.85	-	1763.49 ± 0.35
A. mutabilis	-	1763.49 ± 0.62	-	-	-	4408.72 ± 0.35
Z. nummularia	-	881.74 ± 0.46	-	881.74 ± 0.34	-	881.74 ± 0.34

Seed dispersal: The general pattern of dispersal is presented in Fig. 5. Also seeds dispersed towards east. *C. viscosa* seeds travelled greater distances at site 'B'. However, number of seeds dispersed at site 'B' were significantly ($p<0.001$) greater than site 'A'. *C. viscosa* ($F = 5038.25$, $p<0.001$) showed significant differences in seed numbers at different distances and site ($F = 125.8$, $p<0.001$; $F = 476.05$, $p<0.001$; $F = 588.04$, $p<0.001$ respectively). Interaction of both the factors ($F = 42.99$, $p<0.001$) was also found to be significant.

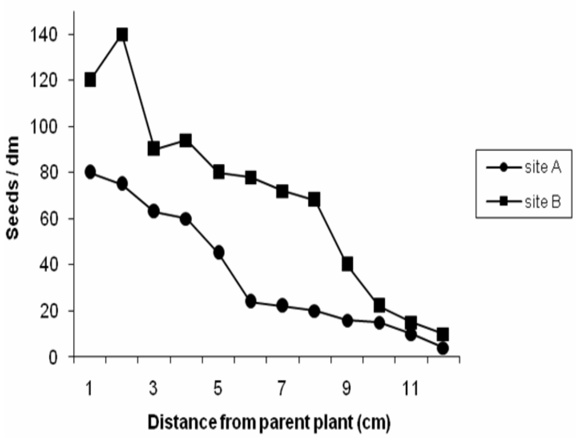

Fig. 5. Dispersal distance (cm) travelled by the seeds of *Cleome viscosa* at site 'A' and 'B.

Soil moisture content: Soil moisture content was lowest in the month of October < September < July. Highest amount of moisture content was recorded in the month of August (Table 6). Moisture content of site 'B' was greater than site 'A. It showed significant differences among months (F = 4.69, p<0.01) and site (F = 20.19, p<0.001). Interaction of month x site also exhibited significant (F = 3.83, p<0.05) differences.

Table 6. Soil moisture content of site 'A' and 'B'.

Month	Soil moisture content (%) at site 'A'	Soil moisture content (%) at site 'B'
July	23.4 ± 0.34	25.3 ± 8 0.2
August	26.7 ± 0.56	28.7 ± 0.42
September	17.4 ± 1.07	22.3 ± 0.32
October	11.5 ± 0.82	13.5 ± 0.72

Discussion

Populations of *C. viscosa* were found to be highly dynamic. Plants complete their life i.e., from germination to seed set in 12 weeks. Rate of mortality is higher in the later stages of life, thus exhibiting Deveey type I (Deveey, 1947), characteristic of annuals. Plants exhibited greater density at site' B' mainly due to better soil moisture regime. Number of individuals increased in the early stages of life and decreased gradually with the passage of time mainly due to the depletion of moisture levels in the soil in the month of September and October. Plant mortality also results to varying degree of grazing (Ter Heerdt *et al*., 1991), pathogens (Burdon *et al*., 1983) and disease (Burdon & Shattock, 1980). High mortality rates at site 'B' might be due to high density. According to Symonides (1988), density dependent mortality regulates population size with varying degree of effectiveness in different species.

At both the sites root dry weights were lowered than other component organs. Such results were also reported for *Ranunculus repens*, *R. acris* and *R. bulbosus* (Sarukhan, 1976). Harper (1977) made the generalization that plants grown in moisture depleted zones tend to adjust their root to shoot ratio in favour of shoots. Stem weights were also greater at site 'B'. Leaf biomass allocated to site 'B' plants was much greater than site 'A' plants. Higher leaf biomass of site 'B' plants increased the photosynthetic functions, thus enhancing the vegetative and reproductive growth of site 'B' plants. The decrease in leaf biomass in the later stages of plant life is associated with an increase in the reproductive structures. Tilman (1988), considered annuals as better competitors because of fast growth resulting from the high proportion of their biomass allocated to leaves in the early stages of life. *C. viscosa* also plants allocate greater vegetative biomass to leaves, but on the onset of flowering large amounts of biomass was diverted to reproduction. Reproductive effort of site 'B' plants was considerably higher than site 'A' plants. Overall, plants from the two sites allocate greater resources to various reproductive functions. Vegetative allocation typically declines with the development of reproductive structures.

Seed banks are helpful in preventing the local extinction of species. They also affect the demography and life history patterns of plant species (Aziz & Khan, 1996; Qaderi *et al*., 2002; Shaukat & Siddiqui, 2004). Site 'B' seed pool contained more seeds than site 'A'. Number of buried seed reserves (m^{-2}) varied among three sampling dates. Seed bank depletion was considerably higher following monsoon showers, due to seedling emergence. Seeds of annual plant species in our study area remain dormant in the soil and recruitment depends on monsoon rain which triggers germination. The seeds germinate at any time during summer when enough moisture is available. Annual species in our study area (site 'A' and 'B') form persistent seed bank presumably because of enforced dormancy. *C. viscosa* is the most abundant species in the seed bank samples followed by *D. muricata* and *I. sindica*. It is due to the fact that number of seeds per fruit in *C. viscosa* sometimes reach up to 30-40 in numbers.

Julliot (1997) suggests three sources of recruitment in any area (i) fresh seed rain, (ii) the seedling bank and (iii) the seed bank. Wind is an effective dispersal agent of annuals in our region due to light weighted seeds. Smaller seeds are usually adapted to long distance dispersal, while larger seeds are more likely to fall near the parent plant. Site 'B' contained taller plants, therefore, seeds travelled greater distances at site 'B' than site 'A'. Short dispersal distances at site 'A' lead to aggregation of individuals which might be due to environmental heterogeneity (Halpern *et al*., 1999; Boudell *et al*., 2002) which affects the mean survivorship and fecundity of species and thus the dynamics. It also affects the outcome of competition between plant species (Pacala, 1987). According to Telenius & Tortstensson (1989) seed dispersal in aggregated habitats is reduced because intervening plants are obstacles to dispersal and vegetation reduces wind speed and alters wind direction. Similar results were also reported by Casper & Grant (1987) in *Cryptantha flava.* He found limited dispersal of *P. lavrifolia* seeds and considered it to ensure the establishment of seedlings within a favourable habitat. Thiede & Augspurger (1996), also demonstrated that surrounding vegetation decreased mean dispersal distance and altered mean dispersal direction. *C. viscosa* seeds at site 'A' and site 'B' travelled greater distances due to their smaller sizes and lighter weights. However, relatively short distances at site 'A' leads to aggregation of individuals. Such aggregations eventually affect the mean survivorship, fecundity and thus dynamics.

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