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EFFECT OF SEED MASS VARIATIONS ON THE GERMINATION AND SURVIVAL OF THREE DESERT ANNUALS

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Abstract

This study is focused on the germination and survival of three desert annual viz., as *Ipomoea sindica* Stapf., *Cleome viscosa* L., and *Digera muricata* Forsk., influenced by the variations in the seed size. The frequency distribution of seed size of each species was constructed and the seeds were sorted out in three over-lapping size classes categorized as small, medium and large. Seed size variations were higher for *I. sindica*, having higher values of coefficient of variation (25.11 %), followed by *C. viscosa* (17.24 %) and *D. muricata* (13.09 %). Large, medium and small-size seeds of three selected species were allowed to germinate. Higher germination rates were observed in large-size seeds followed by medium and small-size seeds. Clear-cut effect of seed size was also observed on growth and survival of plants. Plants emerged from large-size seeds of three species were more likely to survive to maturity. It was due to the fact that large-size seeds have large food reserves, which help them to cope with adverse conditions.

Introduction

Due to uncongenial arid and semi-arid conditions, plants exhibit a variety of variations and adaptations. Seed is the main carrier and source of variation, and its variability of various characters often leads to evolution (Mishra & Sen, 1996). Seed size seems to be an important component in plant fitness (Saeed & Shaukat, 2000). The mean seed size of a population is a product of reconciliation of several conflicting selective forces and possible tradeoffs with seed number (Westoby *et al*., 1996). Both seed size and number are regarded as ecologically important life-history traits and provide increased fitness in various environments (Stamp, 1990).

Seed size of a plant may vary from nearly constant to more than ten-fold (Hawke, 1989). These variations may be genetically or environmentally based. Genetically controlled variations may occur due to differences among embryonic genotypes or differences among maternal genotypes (Krannitz *et al*., 1991). Environmental factors which seem to be responsible for this variation are light intensity, herbivory (Crawley & Nachapong, 1985), temperature (Alexander & Wulff, 1985), pollinator’s effectiveness (Galen *et al*., 1985), nutrient level (Aarsen & Burton, 1990), habitat variation (Mazer, 1989), ovule fertilization time (Thomson & Pellmyr, 1989) and position of an ovule within the ovary (McGinley *et al*., 1990).

According to Bonfil (1998), large seeds tend to produce seedlings that are more likely to establish successfully than seedlings from smaller seeds whereas, studies of Gross & Soule (1981) on *Silene alba* showed that seed size affects the initial seedling growth, but not final seed yield. Positive relationship between seed size and seedling establishment was also reported by Stanton (1984) in wild radish, Weller (1985) in *Lithospermum carolinense*, Tecklin & McCreary (1991) in blue oaks.

Seed polymorphism was also observed in *Ipomoea sindica*, *Cleome viscosa* and *Digera muricata*. They differ in seed mass patterns. Extensive previous work showed that variation in seed mass affects the life-history traits such as percent germination (Alexander & Wulff, 1985), germination time (Zhang & Maun, 1990), plant size (Wulff, 1986), growth rate (Marshall, 1986), competitive ability (Dolan, 1984) and reproductive capacity (Stanton, 1984).

Field conditions, which involve microhabitat variation, either mask or exaggerate seed size effects (Fenner, 1978). Therefore, laboratory studies are required to reveal the effects of varying seed sizes on growth characters both vegetative and reproductive.

This study investigated the variation in seed mass of three selected annual species i.e., *Ipomoea sindica, Cleome viscosa* and *Digera muricata* and examines seed size effects on germination, growth, survival and fecundity of these species.

Materials and Methods

Seeds of *Ipomoea sindica, Cleome viscosa* and *Digera muricata* were collected from Karachi University Campus and stored in airtight glass jars. Seeds with any sign of insect infestation were discarded. Three hundred seeds of each species were randomly selected and weighed individually with an electronic balance. The frequency distribution of seed size of the three species was constructed. Seeds were sorted in three non-overlapping size classes containing seeds weighing 0.0394-0.0474, 0.0475-0.0554 and 0.0555-0.0634 g categorized as small, medium and large respectively in case of *I. sindica*. For *C. viscosa* seeds were divided into 0.0145-0.0237 g as small, 0.0238-0.0329 g as medium and 0.0330-0.0421g as large sized class. For *D. muricata* seeds weighing 0.0038-0.0069 g as small, 0.0070-0.0100 g as medium and 0.0101-0.0132 g as large.

Germination test: Mechanical and chemical scarification (H_2SO_4, 2, 4 and 5N; HCL, 2, 4 and 5N) of seeds was performed. Best germination of all seeds was obtained with 5N H_2SO_4. Ten chemically scarified seeds of each species from all three classes i.e., small, medium and large were placed in 9.5 cm diameter sterilized Petri plates having two layers of Whatman No.1 filter paper, moistened with distilled water. Seeds were germinated in a growth chamber maintained at 35^0C with 14 h light (2000 Lux) and 10 h dark treatment. Each class was replicated thrice. Germination of seeds was observed for 16 days. Seeds were considered to be germinated with the emergence of radical. After two weeks, root and shoot length of the seedlings were recorded. The seedlings were then dried for 48 h at 80^oC, and root, stem and leaves were weighed separately. The germination rate was calculated according to Mugnisjah Nakamura (1986). Percentage germination data were transformed to arcsine square root values before subjecting the data to factorial analysis of variance (FANOVA).

Seedling survival: For each of the three size categories ten seeds were germinated in Petri plates. After one week when emergence had occurred, 6 seedlings of each category were transferred to 40 cm diameter earthen pots containing sandy loam soil. Pots were kept in a greenhouse (humidity 55-60%; temperature 28-30^{o}C). The experiment was performed in a randomized complete block design. Seedling survival was recorded at 10 days interval for 120 days. Plants were harvested after 120 days of growth prior to seed loss. Life tables for the seedling survival data of each size category were constructed. Fecundity per plant was also recorded.

Results

Seed size variation: The seed weight of *Ipomoea sindica* varied from 0.0394 to 0.0634 g (range = 0.0241 g). The mean seed mass of population was 0.0494 g. The seed weight of *Cleome viscosa* varied from 0.0145 to 0.0421 g (range = 0.0277 g), and mean seed mass of this population was 0.0247 g. Whereas, the seed mass of *Digera muricata* varied from 0.0038 to 0.0132 g (range = 0.0094 g).The mean seed weight of population was 0.0095. Frequency distribution of all the three species exhibit peaks when histograms of seeds were drawn (Fig. 1). Summary of statistical parameters (mean, variance, standard deviation, standard error and coefficient of variation) of *I. sindica, C. viscosa* and *D. muricata* are presented in Table 1.

Germination: Seed size had considerable effect on final percentage germination (Fig. 2), as well as germination velocity of all three species (Table 2). Germination velocity was consistently greater for large seeds. In all three species seeds placed in large-sized category gave significantly greater germination percentage (o<0.001) than those placed in medium-size class followed by small-size seeds (Fig. 2).

Germination was significantly ($p<0.001$) affected by seed size as indicated by the results of FANOVA. Root: shoot ratio was significantly higher ($p<0.01$) for seedlings from large-sized seeds followed by medium and small seeds. However, seedling height and root/shoot ratio were greater in *I. sindica* followed by *C. viscosa* and *D. muricata*. Root/shoot ratio was highest in the large-sized seeds of *I. sindica* and lowest in small-sized seeds of *D. muricata* (Tables 3 and 4). Similarly, significant differences ($p<0.001$) in dry weights of seedlings were observed. Higher amounts of dry weights (g) of both root and shoot were observed in the plants emerged from large-sized seeds in all three species (Table 4).

Seedling survival: Mortality seems to be higher in plants developed from small-sized seeds followed by medium and large seeds. Mortality in all three species seems to be age-specific. Mortality rates were lower in the juvenile stages and increased considerably in the later stages of life as illustrated in the life tables (Tables 5-13). Significantly higher dry weights ($p<0.001$) of large seeded plants were recorded in all three species (Table 14), harvested after 120 days of growth. Seed mass of *I. sindica* individuals is higher than those of *C. viscosa* and *D. muricata*, although their fecundity was low. *I. sindica, C. viscosa* and *D. muricata* developed from large and medium-sized seeds flowered at the same time i.e., when plants were 50 days old. While flowering was approximately one week late in plants developed from small seeds in all three species and dry weights allocated to fruits and seeds of large-seeded plants were also significantly higher ($p<0.001$) in the three species (Table 15). Maximum amount of biomass was allocated to reproductive structures of plants that emerged from large seeds of *I. sindica* and the lowest amount of biomass was recorded in the small-seeded individuals of *D. muricata*. In general, reproductive allocation was greater in *I. sindica* followed by *C. viscosa* and *D. muricata* (Table 15). But the common trend, which was observed in all three species, was the highest amount of reproductive output in large-seeded individuals followed by medium and small seeded individuals.

Table 1. Summary of the statistics of *Ipomoea sindica*, *Cleome viscosa* and *Digera muricata* seeds.

Parameters	*I. sindica*	*C. viscosa*	*D. muricata*
Mean	0.0480	0.0294	0.0056
Variance	0.000087	0.00047	0.0000009
Standard deviation	0.0093	0.0068	0.00096
Standard error	± 0.00053	± 0.00039	± 0.000055
Coefficient of variation	19.47	23.36	19.13

Table 2. The effect of seed size on the germination velocity (GV) of *Ipomoea sindica*, *Cleome viscosa* and *Digera muricata* seeds.

Species	Seed Size	GV (%)
I. sindica	Large	48.36
	Medium	26.98
	Small	18.97
C. viscosa	Large	14.27
	Medium	21.75
	Small	11.22
D. muricata	Large	29.82
	Medium	16.65
	Small	19.29

Table 3. The effect of seed size on seedling height (cm) and root/shoot ratio (R/S) of 16 days old seedlings of *Ipomoea sindica*, *Cleome viscosa* and *Digera mricata.*

Species	Seed size	Root length (cm)	Shoot length (cm)	R/S ratio
I. sindica	Large	7.01 ± 0.85 ***	11.29 ± 2.24 ***	0.62
	Medium	5.53 ± 0.22 ***	9.53 ± 1.38 **	0.58
	Small	4.12 ± 0.98 n.s.	7.88 ± 0.62 **	0.52
C. viscosa	Large	6.92 ± 0.34 ***	10.45 ± 2.07 ***	0.66
	Medium	5.84 ± 0.30 *	8.17 ± 0.37 **	0.71
	Small	3.74 ± 0.35 n.s.	7.22 ± 0.70 *	0.51
D. muricata	Large	5.50 ± 0.70 ***	9.33 ± 0.97 ***	0.58
	Medium	3.83 ± 0.55 ***	7.11 ± 0.34 *	0.53
	Small	2.91 ± 0.28 *	6.25 ± 0.74 n.s.	0.46

Table 4. The effect of seed size on root and shoot dry weight (g) of 16 days old seedlings of *Ipomoea sindica*, *Cleome viscosa* and *Digera mricata.*

Species	Seed size	Root weight (g)	Shoot weight (g)
I. sindica	Large	3.12 ± 0.75 ***	4.85 ± 0.98 ***
	Medium	2.38 ± 0.68 *	3.21 ± 0.75 ***
	Small	1.75 ± 0.62 **	2.88 ± 0.73 **
C. viscosa	Large	2.63 ± 0.71 ***	4.02 ± 0.65 ***
	Medium	1.87 ± 0.58 **	2.35 ± 0.59 **
	Small	1.24 ± 0.44 n.s.	2.08 ± 0.53 *
D. muricata	Large	1.93 ± 0.37 ***	2.87 ± 0.47 ***
	Medium	0.94 ± 0.28 ***	1.73 ± 0.58 **
	Small	0.77 ± 0.22 *	0.98 ± 0.42 n.s.

Note: Level of significance; * = $p<0.01$, ** = $p<0.01$, *** = $p<0.001$; n.s. = Non-significant.

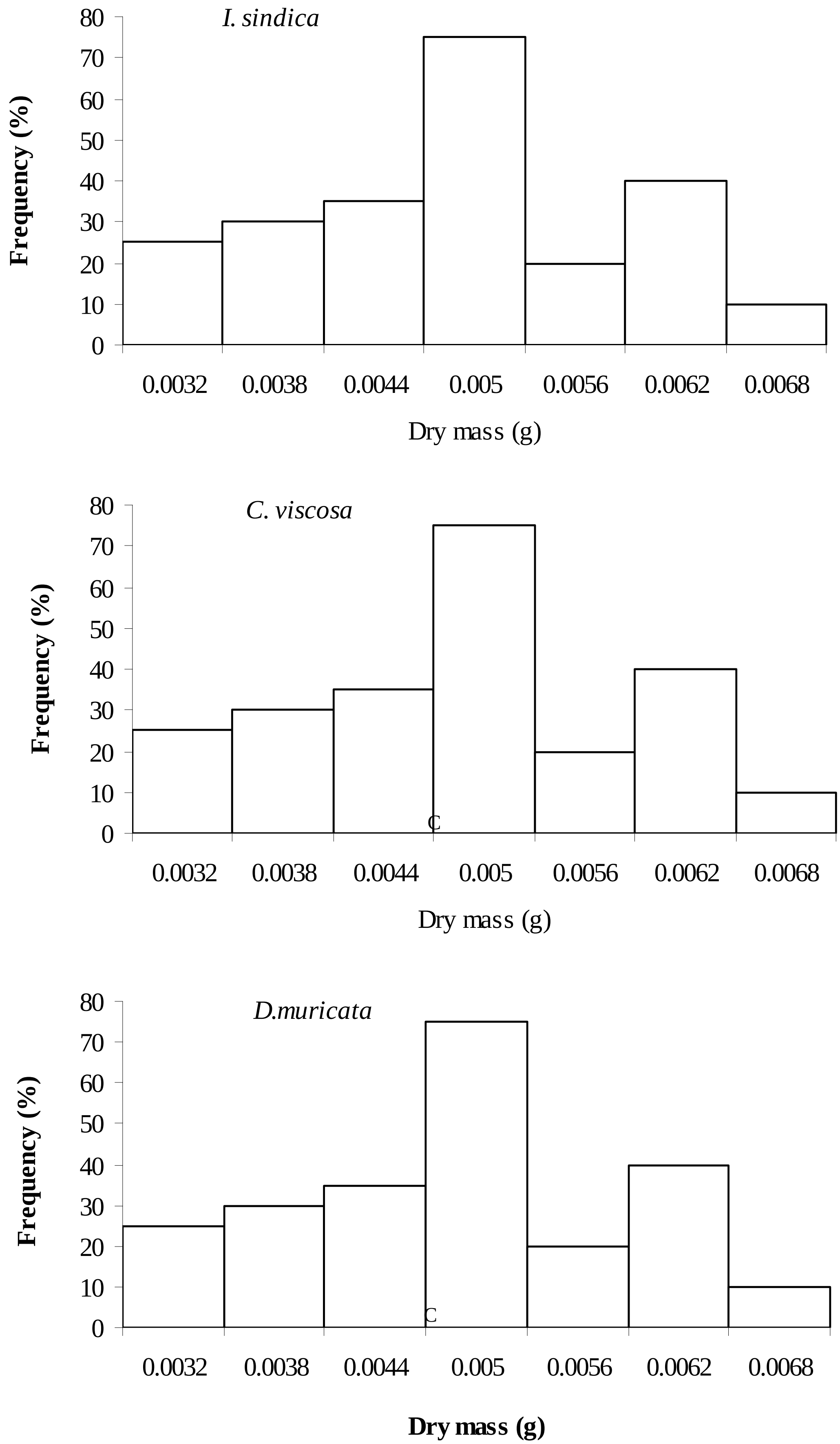

Fig. 1. The frequency distribution of the seed weight of (g) *Ipomoea sindica, Cleome viscosa* and *Digera muricata*.

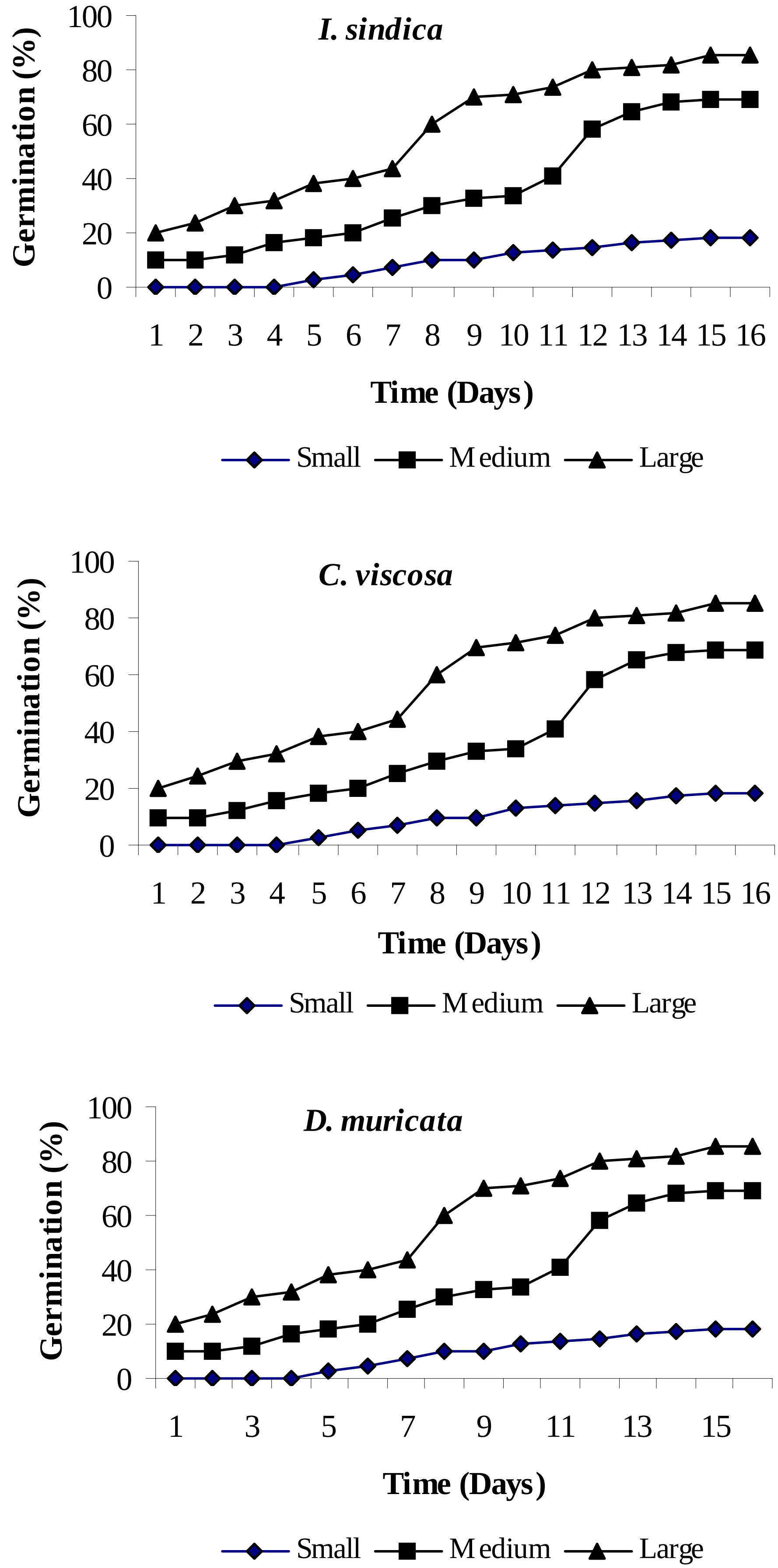

Fig. 2. Cumulative germination percentages over time of *Ipomoea sindica*, *Cleome viscosa* and *Digera muricata* seeds belonging to three size categories.

Table 5. Life table of *Ipomoea sindica* plants experimentally grown from large size seeds.

Age (x) (days)	Numbers surviving (lx)	Numbers dying (dx)	Stationary population (Lx)	Residual life-span (Tx)	Age specific mortality (qx)	Expectancy of further life (ex)
10	1000.00	0.00	0.00	53.33	0.00	0.05
20	1000.00	0.00	16.67	53.33	0.00	0.05
30	1000.00	33.34	50.00	546.66	0.03	0.51
40	966.00	66.66	91.66	46.66	0.06	0.04
50	900.00	116.67	75.00	375.00	0.12	0.41
60	783.33	33.33	41.66	300.00	0.42	0.30
70	750.00	50.00	75.00	258.34	0.06	0.34
80	700.00	100.00	25.00	183.34	0.14	0.26
90	600.00	50.00	66.67	158.34	0.08	0.26
100	550.00	83.34	66.67	91.67	0.15	0.16
110	466.00	50.00	25.00	25.00	0.10	0.05
120	416.00	-	-	-	-	-

Table 6. Life table of *Ipomoea sindica* plants experimentally grown from medium size seeds.

Age (x) (days)	Numbers surviving (lx)	Numbers dying (dx)	Stationary population (Lx)	Residual life-span (Tx)	Age specific mortality (qx)	expectancy of further life (ex)
10	1000.00	0.00	1000.00	7574.95	0.00	7.57
20	1000.00	66.67	966.66	6574.95	0.06	6.57
30	933.33	50.00	908.33	5608.29	0.05	6.00
40	883.33	83.33	841.66	4699.96	0.09	5.32
50	800.00	50.00	775.00	3858.30	0.06	4.82
60	750.00	50.00	725.00	3083.30	0.06	4.11
70	700.00	116.67	641.66	2358.30	0.16	3.36
80	583.33	50.00	558.33	1716.64	0.08	2.94
90	533.33	33.33	516.66	1158.31	0.06	2.17
100	500.00	216.67	391.66	641.65	0.43	1.28
110	283.33	66.67	249.99	249.99	0.23	0.88
120	216.66	-	-	-	-	-

Table 7. Life table of *Ipomoea sindica* plants experimentally grown from small size seeds.

Age (x) (days)	Numbers surviving (lx)	Numbers dying (dx)	Stationary population (Lx)	Residual life-span (Tx)	Age specific mortality (qx)	expectancy of further life (ex)
10	1000.00	50.00	58.33	974.65	0.05	0.97
20	950.00	66.67	75.00	916.32	0.07	0.96
30	883.33	83.33	58.33	841.32	0.09	0.95
40	800.00	33.34	108.33	782.99	0.04	0.97
50	766.66	183.33	108.33	674.66	0.23	0.87
60	583.33	33.33	41.66	566.33	0.05	0.97
70	550.00	50.00	50.00	524.67	0.09	0.95
80	500.00	50.00	50.00	474.67	0.01	0.94
90	450.00	50.00	116.67	424.67	0.11	0.94
100	400.00	183.34	200.00	308.00	0.45	0.77
110	216.66	216.66	108.00	108.00	1.00	0.49
120	0.00	-	-	-	-	-

Table 8. Life table of Cleome *viscosa* plants experimentally grown from large size seed.

Age (x) (days)	Numbers surviving (lx)	Numbers dying (dx)	Stationary population (Lx)	Residual life-span (Tx)	Age specific mortality (qx)	expectancy of further life (ex)
10	1000.00	0.00	0.00	1416.99	0.00	1.41
20	1000.00	0.00	0.00	1416.99	0.00	1.41
30	1000.00	0.00	50.00	1416.99	0.00	1.41
40	900.00	1.00	50.00	916.99	0.11	1.01
50	883.33	00.00	133.33	866.99	0.00	0.98
60	833.33	266.67	333.33	733.66	0.32	0.88
70	616.66	66.66	108.33	400.33	0.10	0.64
80	550.00	150.00	100.00	929.00	0.27	0.53
90	400.00	150.00	75.00	192.00	0.12	0.48
100	350.00	100.00	83.50	117.00	0.28	0.33
110	250.00	67.00	33.50	33.50	0.26	0.13
120	183.33	0.00	-	-	0.00	0.0

Table 9. Life table of cleome *viscosa* plants experimentally grown from medium size seeds.

Age (x) (days)	Numbers surviving (lx)	Numbers dying (dx)	Stationary population (Lx)	Residual life-span (Tx)	Age specific mortality (qx)	expectancy of further life (ex)
10	1000.00	166.67	124.99	916.66	0.16	0.91
20	883.33	83.33	66.66	791.64	0.09	0.89
30	750.00	50.00	41.67	724.98	0.06	0.96
40	700.00	33.34	41.67	683.31	0.04	0.97
50	666.66	50.00	41.67	341.64	0.07	0.96
60	616.66	33.33	125.00	599.97	0.05	0.97
70	583.33	216.67	125.00	474.97	0.37	0.81
80	366.66	33.33	66.66	349.97	0.09	0.95
90	333.33	100.00	75.00	283.31	0.30	0.84
100	233.33	50.00	116.65	208.31	0.21	0.89
110	183.33	183.33	91.66	91.66	1.00	0.49
120	0.00	-	-	-	-	-

Table 10. Life table of *Cleome viscosa* plants experimentally grown from small size seeds.

Age (x) (days)	Numbers surviving (lx)	Numbers dying (dx)	Stationary population (Lx)	Residual life-span (Tx)	Age specific mortality (qx)	expectancy of further life (ex)
10	1000.00	250.00	875.00	4527.96	0.25	4.52
20	750.00	16.67	741.66	3652.96	0.02	4.87
30	733.33	200.00	633.33	2911.30	0.27	3.96
40	533.33	33.33	516.66	2277.97	0.06	4.27
50	500.00	83.34	458.33	1661.31	0.16	3.52
60	416.66	33.33	399.99	1302.98	0.07	3.12
70	383.33	50.00	358.33	902.99	0.13	2.35
80	333.33	83.33	291.66	544.66	0.24	1.63
90	250.00	50.00	225.00	325.00	0.20	1.30
100	200.00	200.00	100.00	100.00	1.00	0.50
110	0.00	0.00	0.00	0.00	0.00	0.00
120	0.00	0.00	-	-	-	-

Table 11. Life table of *Digera muricata* plants experimentally grown from large size seeds.

Age (x) (days)	Numbers surviving (lx)	Numbers dying (dx)	Stationary Population (Lx)	Residual life-span (Tx)	Age specific mortality (qx)	expectancy of further life (ex)
10	1000.00	83.34	66.67	957.98	0.08	0.95
20	916.66	50.00	66.66	891.31	0.05	0.97
30	866.66	83.33	75.00	824.65	0.09	0.95
40	783.33	66.67	75.00	749.65	0.08	0.95
50	716.66	83.33	150.00	674.65	0.11	0.94
60	633.33	216.67	116.65	524.65	0.34	0.82
70	416.66	16.66	33.33	408.00	0.03	0.97
80	400.00	50.00	66.36	374.67	0.12	0.93
90	350.00	83.34	66.67	308.00	0.23	0.88
100	266.66	50.00	133.33	241.33	0.18	0.90
110	216.66	216.66	108.00	108.00	1.00	0.49
120	-	-	-	-	-	-

Table 12. Life table of *Digera muricata* plants experimentally grown from medium size seeds.

Age (x) (days)	Numbers surviving (lx)	Numbers dying (dx)	Stationary population (Lx)	Residual life-span (Tx)	Age specific mortality (qx)	expectancy of further life (ex)
10	1000.00	216.67	891.66	4233.28	0.21	4.23
20	783.33	66.67	749.99	3341.62	0.08	4.26
30	716.66	133.33	64.99	2591.63	0.18	3.61
40	583.33	50.00	558.33	1941.64	0.08	3.32
50	533.33	100.00	483.33	1383.31	0.18	2.59
60	433.33	133.33	366.66	899.98	0.30	2.07
70	300.00	33.34	283.33	533.32	0.11	1.77
80	266.66	33.33	133.33	249.99	0.12	0.93
90	233.33	233.33	116.66	116.66	1.00	0.49
100	0.00	-	-	-	-	-
110	0.00	-	-	-	-	-
120	0.00	-	-	-	-	-

Table 13. Life table of *Digera muricata* plants experimentally grown from small size seeds.

Age (x) (days)	Numbers surviving (lx)	Numbers dying (dx)	Stationary population (Lx)	Residual life-span (Tx)	Age specific mortality (qx)	expectancy of further life (ex)
10	1000.00	366.67	816.66	2716.46	0.36	2.71
20	633.33	183.33	541.66	1899.80	0.28	2.99
30	450.00	66.67	416.66	1358.14	0.14	3.01
40	383.33	83.33	341.66	941.48	0.21	2.45
50	300.00	33.34	283.33	599.89	0.11	1.99
60	266.66	83.33	224.99	316.49	0.31	0.49
70	183.33	183.33	91.50	91.50	1.00	1
80	0.00	-	-	-	-	-
90	0.00	-	-	-	-	-
100	0.00	-	-	-	-	-
110	0.00	-	-	-	-	-
120	0.00	-	-	-	-	-

Table 14. The effect of seed size on below and above-ground weight (g) of *Ipomoea sindica, Cleome viscosa* and *Digera muricata*. (mean ± std. error)

Species	Seed size	Below-ground weight (g)	Above-ground weight (g)	No. of seeds / plant
I. sindica	Large	25.22 ± 0.15 ***	38.17 ± 0.22 ***	110.0 ± 1.65 ***
	Medium	18.28 ± 0.30 **	29.16 ± 0.28 ***	95.0 ± 1.20 **
	Small	11.00 ± 0.30 *	25.85 ± 0.17 n.s.	50.0 ± 0.73 *
C. viscosa	Large	16.40 ± 0.22 ***	30.20 ± 0.32 ***	660.2 ± 2.45 ***
	Medium	14.24 ± 0.18 ***	22.40 ± 0.45 **	542.3 ± 1.63 ***
	Small	8.40 ± 0.25**	18.48 ± 0.71 **	315.6 ± 1.55 **
D. muricata	Large	14.00 ± 0.23 ***	23.80 ± 0.65 ***	20.5 ± 0.50 ***
	Medium	7.04 ± 0.24 *	15.04 ± 0.81 **	16.0 ± 0.63 **
	Small	5.04 ± 0.32 **	9.60 ± 0.25 n.s.	8.0 ± 0.53 *

Note: Level of significance; * = p<0.01, ** = p<0.01, *** = p<0.001; n.s. = Non-significant

Table 15. The effect of seed size on the reproductive structures of *Ipomoea sindica, Cleome viscosa* and *Digera muricata*. (mean ± std. error)

Species	Seed size	No. of fruits / plant	No. of seeds / plant
	Large	25.0 ± 0.21 **	110.0 ± 1.65 ***
I. sindica	Medium	20.0 ± 0.11 **	95.0 ± 1.20 **
	Small	13.0 ± 1.21 *	50.0 ± 0.73 *
C. viscosa	Large	22.0 ± 1.20 ***	660.2 ± 2.45 ***
	Medium	18.0 ± 0.32 ***	542.3 ± 1.63 ***
	Small	11.0 ± 0.75 n.s.	315.6 ± 1.55 **
D. muricata	Large	20.0 ± 0.50 ***	20.5 ± 0.50 ***
	Medium	16.0 ± 0.63 **	16.0 ± 0.63 **
	Small	8.0 ± 0.53 n. s.	8.0 ± 0.53 *

Note: Level of significance; * = p<0.01, ** = p< 0.01, *** = p<0.001; n.s. = Non-significant

All the three species followed Deveey type III curve, characteristic of annuals. The comparison of curves using Mentel-Haenszel chi-square test showed significant differences between the curves pertaining to large and those of small seeds for *I. sindica, C. viscosa* and *D. muricata* (X^2 = 40.86, p<0.001; X^2 = 71.735, p<0.001 and X^2 = 64.612, p<0.001 for I. *sindica, C. viscosa* and *D. muricata* respectively). While, the curves corresponding to medium and small seeds were non-significant for *I. sindica* and *C. vicsosa* (X^2 = 18.793 and 16.490 respectively) and significant for *D. muricata* (X^2 = 23.508, p<0.01). However, significant differences were observed between the curves corresponding to large and medium seeds of *C. viscosa* (X^2 = 32.820, p<0.001) and *D. murticata* (X^2 =32.324, p<0.01). Whereas, *I. sindica* exhibited non-significant curve differences between large and medium seeds (X^2 = 10.977).

Discussion

Nature favors those individuals, which represent adaptive compromises. The production of seeds of varying size is capable of germinating under varying environmental conditions. According to Zhang & Maun (1990), variation in seed size of a species may be of ecological significance in a number of ways. For example, large seeds may produce higher percentage germination, have higher rate of germination and produce higher seedling weight. Considerable differences in the seed size have also been observed among different populations in the field (Melzack & Watts, 1982) and in comparisons between field and glasshouse grown populations.

Percentage germination is evidently affected by seed size. In small sized seeds 70%, 60% and 30% of germination was recorded in *I. sindica*, *C. viscosa* and *D. muricata*, respectively. Whereas, in large and medium sized seeds 100% germination was noted. Rate of germination was higher in large seeds than in medium and small seeds of all three species. Shaukat *et al*., (1999), also found higher germination percentages in large seeds of *Acacia nilotica*. Similar results were also reported by Springer (1991) in *Andropogon gerardii*, Aiken & Springer (1995) in six switch grass cultivars, Saeed & Shaukat (2000) in *Senna occidentalis*. Greipsson & Davy (1994) reported high germination rates and rapid establishment in large-sized seeds of *Leymus arenarius*. On the other hand, Stamp (1990) found decreased rate of germination in larger seeds of *Medicago sativa* and *Erodium brachycarpum* respectively while Zhang & Maun (1990); Shipley & Parent (1991) found no effect of seed size on final seed germination percentages.

In all three species, there is a clear effect of seed size on seedling growth, both initially and in the later stages of growth. These results corroborate the findings of Bonfil (1998), which showed that seedlings of *Quercus rugosa* and *Q. laurina* originating from large seeds can better endure loss of cotyledons and aerial biomass and thus are better equipped to confront stress. Positive relationships between seed and seedling size / weight was also reported by Tripathi & Khan (1990), Tecklin & McCreary (1991).

Significant effect of seed size on the survival and growth of three annuals were also observed. Germination, plant size and plant growth (vegetative and reproductive) with reference to seed size was most affected in *D. muricata* followed by *C. viscosa* and *I. sindica.* Overall plant fitness in *D. muricata* was greatly influenced by varying seed size. Seedlings from large seeds had the highest growth rates and vegetative as well as reproductive growth than those emerged from medium and small sized seeds. Moreover, seedlings produced from small seeds were short-lived, exhibiting low productivity. Marshall (1986) studied the effect of seed size on seedling success in three *Sesbania spp*., and found that large-seeded species produced seedlings that survived the longest while the small-seeded species produced seedlings that were relatively short-lived. Aarssen & Burton (1990), however, found the inverse relationship between seed size and seedling survival in *Senecio vulgaris* due to variation in soil nutrient gradient. Whereas, Krannitz *et al*., (1991) reported genetically based differences on seed size and seedling survival in *Arabidopsis thaliana*. These differences in seed size have been linked to a number of fitness components such as germination rate and growth rate that affect the probability of a seedling surviving to maturity

Increased dry weights of plants with an increase in size of seeds were observed in *I. sindica*, *C. viscosa* and *D. muricata*. Maximum dry weights obtained in plants derived from large seeds were also reported by Foster & Janson (1985) and Shaukat *et al*., (1999). *I. sindica* produced smaller number of heavier seeds whereas, *C.viscosa* and *D. muricata* produced lighter seeds in large numbers. Seed parents usually allocate resources to produce smaller number of larger seeds, just to prevent seed mass as resources decline (Winn, 1991). Therefore, the large seeded species i.e., *I. sindica* is not the highest offspring production species, as is also reported in *Sesbania* spp., (Marshall, 1986). Decreased seed weight can be disadvantageous, because small-sized seeds are associated with lower germination percentage, smaller seedling size / weight and lower reproductive output. Thus, it decreases the chances of seedling establishment and survival to reproduction (Krannitz *et al*., 1991).

Our studies have shown that seed size affects a number of characteristics that influence the probability of germination, survival, growth and reproduction. Large seeds produced seedlings that were more likely to survive to maturity than seedlings from smaller seeds. It might be due to large food reserves in large seeds, which helps them to cope with adverse conditions. Moreover, seedlings from large seeds produced larger roots, which penetrate deeper into soil and spread to a greater extent, which eventually favors their survival by increasing the resource capture and decreasing the chances of desiccation.

Safe-site availability is low in arid and semi-arid areas. Safe-sites usually differ for seeds of different sizes. According to Winn (1991), safe-site requirements of small seeds are more restrictive than those for large seeds. Thus, large seed size is advantageous, because they are not much restricted for safe-site requirements. Remarkable polymorphism in the seed size of *I. sindica, C. viscosa* and *D. muricata* assures their survival and successful establishment in xeric conditions with a variety of microhabitats. Variation in seeds size also plays a significant role in the evolutionary success of species.

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