

## Role of seed banks in the dynamics of desert communities

M. Ajmal Khan, Farhat Agha and Bilquees Gul

*Department of Botany, University of Karachi, Karachi-75270, Pakistan*

### Abstract

Sub-tropical deserts of Karachi, Pakistan are dominated by perennial shrubs and grasses, usually in a mono-specific stands. Seed bank dynamics of three stands about a kilometer away from the coast were selected and monitored for 2 years. These stands were dominated by *Atriplex stocksii*, *Cyperus arenarius* and *Cressa cretica*, respectively, with few individuals of other species in each stand. Soil analysis of the *C. arenarius* community showed seeds of *A. stocksii* and *C. arenarius* were present throughout both of the seasons; however, only *A. stocksii* maintained a persistent seed bank that had some relationship with the aboveground vegetation. The *C. cretica* dominated community had a substantial presence of *C. arenarius* seed in the soil with some seeds of *C. cretica*, *Salsola imbricata* and *A. stocksii*. However, *C. cretica* maintained a small persistent seed bank showing a close relationship between seed bank and vegetation. *A. stocksii* maintained a large persistent seed bank during both seasons indicating a good seed bank-vegetation relationship.

### Introduction

Seed banks may play a significant role in determining the spatial and temporal distribution of halophytes [1]. Salt marsh environments are unfavorable for most plants because of high salinity, drought and flooding stress [2–7]. When conditions for seed germination are not favorable and beyond the tolerance limits for species, un-germinated seeds of halophytes often maintain enforced dormancy in the soil and serve as a transient or persistent seed bank [8–10]. Seed bank size may vary considerably in coastal salt marshes and some community types have large persistent seed banks [11] and others contain few or no seeds in the seed bank [9, 10, 12, 13]. Perennial species usually do not form a persistent seed bank, e.g., east and west coast of North America [14, 15], and in seed banks of sub-tropical coast of Karachi [3, 4]. However, since annual species of halophytes have only a single opportunity to reproduce in their life history, seed banks play a more significant role in determining their spatial and temporal distribution than that of perennials, which generally reproduce through ramets [16–18].

The relationship between seed banks and aboveground vegetation in marsh communities is apparently quite variable [1]. In some systems there is a high similarity between the aboveground vegetation of salt marsh zonal communities and the seed bank [7, 19], whereas in other marsh communities fewer similarities are reported [9, 10, 20, 21]. Zaman and Khan [22] determined that the seed bank and aboveground vegetation of salt deserts were similar in species composition in communities around Karachi. In contrast, Khan [23] reported that the seed bank of a salt desert inland community had a high diversity in comparison to those occurring in aboveground plant communities. *Suaeda fruticosa* seeds formed a persistent seed bank, while other species such as *Haloxylon stocksii* and *C. cretica* had a transient seed bank. Coastal communities were found to have only a small seed bank with 113 seeds  $m^{-2}$  or less [3]. Communities dominated by *Arthrocnemum indicum*, *A. macrostachyum*, *S. fruticosa*, *Halopyrum mucronatum*, *Cenchrus pennisetiformis* and *A. stocksii* have an aboveground vegetation similar in species composition to that of the seed bank.

Salt deserts tend to have smaller persistent seed banks than do salt marshes, and only a small number of salt desert perennial species are apparently able to produce a persistent seed bank [23]. Seeds of salt desert species are exposed to stresses like high temperature, drought, and salinity and their interactions. Khan [24] and Zaman and Khan [22] showed that salt desert species in the Karachi region, including *C. cretica*, *H. stocksii*, *S. imbricata* and *Sporobolus ioclados* had a transient seed bank that was depleted after monsoon rains. *S. fruticosa*, however, maintained a persistent seed bank of 233–981 seeds  $m^{-2}$  [24]. The seed numbers of *C. cretica*, *S. imbricata*, and *S. ioclados* in the seed bank varied seasonally, decreasing from February until May, and by June there were few seeds in the seed bank [22]. The seed bank of *S. fruticosa* varied in size during the growing season, and ranged from a low of 317 seeds  $m^{-2}$  in October to a high of 917 seeds  $m^{-2}$  in February [23]. *H. stocksii* and *C. cretica* followed a similar pattern, with low values of 2 and 2.5 seeds  $m^{-2}$  and high values of 37 and 26 seeds  $m^{-2}$  for the two species, respectively. Aziz and Khan [25] reported that *C. cretica* had a seed bank of 2800 seeds  $m^{-2}$  in May in a sand dune near the coast of Karachi. From January to December the seed bank decreased from 1600 to 300 seeds  $m^{-2}$  and with the dispersal of new seeds the number of seeds in the seed bank increased to 2800 seeds  $m^{-2}$ . There was very low recruitment by seeds in these salt desert habitats because of the intense environmental stress caused by high temperatures, low soil moisture, and high salinity to which seeds are exposed [25]. Gul and Khan [26] reported a larger seed bank in the inter-tidal community of *A. macrostachyum* approaching a maximum of 917 135 seeds  $m^{-2}$ . The number decreased after a few months but the community still maintained a substantial size of the seed bank.

It is evident from the above that the role of the seed bank in proximate and ultimate success of various plant populations is still far from clear. The

present research was, therefore, carried out in the coastal region of Pakistan to test the hypothesis that the seed bank has a prominent role in the success of saline desert communities.

### Study site

The studies were conducted from 1999 to 2002 in communities located about a kilometer away from the Gizri Creek, Karachi, Pakistan (24°57'07.99" N, 66°45'23.74" E). The soil was dry, loamy sand and the vegetation was dominated by salt tolerant grasses and shrubs. In this geographical region there are only two seasons: a long summer and a short winter. Monthly mean ambient summer and winter temperatures are 36°C and 25°C, respectively. The monsoon season extends from June to September. The study location is just beyond the area that receives direct inundation. Various pure communities dominated by *A. stocksii* (Chenopodiaceae), *S. fruticosa* (Chenopodiaceae), *Aeluropus lagopoides* (Poaceae), *H. mucronatum* (Poaceae), and *C. cretica* (Convolvulaceae) were found. The present study was conducted on the communities dominated by *A. stocksii*, *C. cretica* and *C. arenarius* because they are among the few most frequently found communities around supra-littoral areas of Karachi, Pakistan.

### Vegetation and seed bank sampling

The vegetation in each community was analyzed by the point-centered quarter method [27]. Density, frequency and cover were measured and an importance value index calculated using data from 20 sample points. To assess the size and species composition of the seed bank, 20 randomly selected soil cores were collected using a 1.5-cm diameter corer to a depth of 15 cm at monthly intervals from November 1999 to October 2002. Seeds were manually sorted immediately after collection with the help of a binocular microscope, identified using a reference collection and counted. Seeds that appeared intact and viable were included in the count. A seed viability test was carried out using Tetrazolium chloride test.

### Salient findings of the study

The three communities studied showed a low species diversity (Tab. 1). Few individual species of other than the dominant species were found. Seasonal profile of the *C. arenarius* seed bank indicated the presence of seeds of *A. stocksii* and *C. arenarius* seeds throughout both seasons (Tab. 2). Most *C. arenarius* seeds were dead, but *A. stocksii* maintained a persistent seed bank showing little relationship with vegetation (Tab. 3). Seeds of other species disappeared soon after dispersal.

**Table 1.** Species composition of three coastal communities showing relative density (RD), relative frequency (RF) and relative cover (RC) for each species.

Species	Plant community								
	<i>Atriplex stocksii</i>			<i>Cressa cretica</i>			<i>Cyperus arenarius</i>		
	RD	RF	RC	RD	RF	RC	RD	RF	RC
<i>Atriplex stocksii</i>	70	80	92	0	0	0	1	1	7
<i>Cressa cretica</i>	3	3	1	96	76	96	0	0	0
<i>Cyperus arenarius</i>	15	7	2	0	0	0	97	97	84
<i>Heliotropium subulatum</i>	1	2	1	0	0	0	1	1	5
<i>Suaeda fruticosa</i>	10	8	4	4	24	4	1	1	4

The *C. cretica*-dominated community had a substantial presence of *C. arenarius* seeds in the soil (Tab. 4) with a small presence of *C. cretica*, *S. imbricata* and *A. stocksii*. However, *C. cretica* maintained a small persistent seed bank (Tab. 5) with some seeds of *A. stocksii*, *C. arenarius* and *S. imbricata*. Here a close relationship between seed bank and vegetation was witnessed.

The *A. stocksii* community showed relatively higher number of its seeds throughout both the seasons. Seeds of *C. cretica*, *C. arenarius* were also present (Tab. 6). However, a persistent seed bank was maintained by *A. stocksii* during both seasons (Tab. 7), indicating a good seed bank-vegetation relationship.

The role of the seed bank in regulating dynamics of perennial shrub communities is far from clear [1, 26, 28]. Perennial shrubs and grasses produce a large number of seeds but the recruitment from seeds is either rare or infrequent [3, 4]. The size of the seed bank also varies considerably in salt marsh and salt desert habitats [1, 6, 7, 20, 23, 29, 30]. Investigations in coastal salt marshes indicate that some community types have large persistent seed bank [11, 26], while others contains few or no seeds in the seed bank [3, 4, 12, 31]. The present study showed a small sized seed bank in the near coastal communities dominated by perennial shrubs. The largest number of seeds found here was 53078 seed m<sup>-2</sup>; however, the number of viable seeds among them was reduced to 4423 seed m<sup>-2</sup>. It appears that the actual seed bank may be much smaller than previously reported. For example, Gul and Khan [26] reported 917135 seeds m<sup>-2</sup>, probably one of the largest seed bank in the inter-tidal coastal marsh near Karachi. However, little recruitment was reported from the seed bank. When the viability of seeds from the seed bank was investigated most of them were found to be dead (Khan, unpublished data).

The unpredictability or harshness of the environment may be a significant factor in determining the nature of a persistent seed bank [1]. Environmental conditions may play a significant role in determining the longevity of seed banks. Tolerance at the germination stage can be determined by measuring two factors: the capacity of seeds to remain viable under hyper-saline conditions and the maximal salinity limit at which germination occurs [1]. There are



Table 3. Number ( $m^{-2}$ ) of viable seeds in the seed bank of *Cyperus arenarius* community.

Month	<i>Atriplex stocksii</i>		<i>Cressa cretica</i>		<i>Cyperus arenarius</i>		<i>Tribulus longipetalus</i>	
	1999-2000	2001-2002	1999-2000	2001-2002	1999-2000	2001-2002	1999-2000	2001-2002
Nov	0 ± 0	0 ± 0	1769 + 133	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Dec	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Jan	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	1769 + 134
Feb	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	885 ± 88	0 ± 0	0 ± 0
Mar	885 ± 84	885 ± 84	885 ± 84	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Apr	885 ± 84	0 ± 0	2654 + 186	0 ± 0	0 ± 0	0 ± 0	0 ± 0	3539 + 144
May	885 ± 84	0 ± 0	2654 + 188	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Jun	0 ± 0	885 ± 84	0 ± 0	0 ± 0	885 ± 84	0 ± 0	0 ± 0	0 ± 0
Jul	1769 ± 133	0 ± 0	0 ± 0	0 ± 0	0 ± 0	885 ± 84	0 ± 0	0 ± 0
Aug	0 ± 0	885 ± 84	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Sep	885 ± 84	0 ± 0	0 ± 0	1769 + 133	0 ± 0	885 ± 84	0 ± 0	0 ± 0
Oct	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	885 ± 84	0 ± 0	885 ± 84

several reports that indicate the differential responses of halophytic seeds to harsh environmental conditions. In cool moist habitats, usually dominated by annuals, when seeds were exposed to hyper-saline conditions, they remained in an enforced dormancy state that was released by exposing seeds to fresh water [8–10, 32–35], while increase in salinity caused a substantial reduction in seed germination of cold desert species like *Chrysothamnus nauseosus* and *Sarcobatus vermiculatus* [36]. The present study showed that seeds from perennial shrubs growing in hot and hyper-saline conditions of subtropical desert are dead except for some species like *A. stocksii*, which maintain a very small but viable bank.

The relationship between seed bank and aboveground vegetation in saline communities is apparently quite variable [1, 19, 32, 37]. In some systems there is a high similarity between the aboveground vegetation of salt marsh zonal communities and their seed banks [19, 38], whereas in other marsh communities low similarities are reported [9, 10, 20, 21, 39]. The Arabian Sea coast communities showed a close relationship between vegetation and seeds of flora found in the soil [3, 4, 28]. The present study showed that more seeds of the dominant species occur in the seed bank. However, except for *A. stocksii* and *C. cretica* seeds of all other species either disappear completely from the soil or lose their viability. Size of the seed bank for both *A. stocksii* and *C. cretica* was also substantially reduced either through predation or the loss of viability.

Most of the initial work on the seed bank dynamics was conducted on the cool, moist salt marshes. Halophytes native to those areas were reported to be highly tolerant to salinity and temperature stress while in the soil [1, 8, 35, 40], and when salinity and temperature stress were removed they germinated readily. They also maintained a larger seed bank, which plays a significant role in both evolutionary and ecological success of the marsh ecosystem. Seed bank studies reported for the arid sub-tropical communities dominated by perennial shrubs and grasses showed an entirely different pattern. Most of the shrubs are reported to produce millions of seeds; however, after dispersal seeds disappear quickly. Seeds of only some species remain in the soil including *A. stocksii*, *C. cretica*, *A. macrostachyum* and *S. fruticosa* [3, 22, 23, 25, 26]. However, except for *A. stocksii* and *S. fruticosa*, the recruitment of the species through seeds is rare. The present study and other related unpublished work being carried out indicate that seeds of those species that are represented by either large or small numbers lose their viability and therefore are not part of the seed bank. This explains the lack of recruitment through seedlings. Our data also indicate that a number of previous studies that lack information on the viability of seeds would lead to erroneous interpretations. The results presented in this study validate the hypothesis that the seed bank has a role in contributing to the fitness of some perennial shrub populations in arid habitats; however, their main role appears to be to maximize fitness by occasionally contributing fresh genotypes to the gene pool of the population, which primarily rely on duplicating the successful genotypes. Further studies on the role of seed banks under saline desert conditions are in progress.



Table 5. Number ( $m^{-2}$ ) of viable seeds in the seed bank of *Cressa cretica* community.

Month	<i>Atriplex stocksii</i>		<i>Cressa cretica</i>		<i>Cyperus arenarius</i>		<i>Salsola imbricata</i>	
	1999-2000	2001-2002	1999-2000	2001-2002	1999-2000	2001-2002	1999-2000	2001-2002
Nov	0 ±0	0 ±0	0 ±0	4423 ±197	1769 ±133	0 ±0	0 ±0	0 ±0
Dec	0 ±0	885 ±89	0 ±0	0 ±0	885 ±89	0 ±0	0 ±0	0 ±0
Jan	0 ±0	0 ±0	0 ±0	2653 ±1876	0 ±0	2654 ±187	0 ±0	0 ±0
Feb	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	885 ±89	0 ±0	0 ±0
Mar	0 ±0	0 ±0	885 ±89	885 ±89	0 ±0	0 ±0	0 ±0	0 ±0
Apr	0 ±0	885 ±89	1769 ±133	1769 ±133	0 ±0	885 ±89	0 ±0	0 ±0
May	885 ±89	885 ±89	0 ±0	0 ±0	0 ±0	885 ±89	0 ±0	0 ±0
Jun	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0
Jul	885 ±89	0 ±0	885 ±89	1769 ±133	885 ±89	0 ±0	0 ±0	0 ±0
Aug	885 ±89	0 ±0	0 ±0	0 ±0	0 ±0	885 ±89	885 ±89	0 ±0
Sep	885 ±89	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0
Oct	0 ±0	0 ±0	0 ±0	5308 ±196	0 ±0	0 ±0	0 ±0	0 ±0





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