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POPULATION CHARACTERISTICS OF THE COASTAL HALOPHYTE *ARTHROCNEMUM MACROSTACHYUM*

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Abstract

Seed bank and morphological characteristics of *Arthrocnemum macrostachyum* population along an inundation gradient are described. The seed density increased substantially from lower marsh (2987 seed m^{-2}) to upper marsh (141,509 seed m^{-2}). The seed bank contained only dominant species in the lower marsh, however, the number of species in the seed bank increased towards the upper marsh. *A. macrostachyum* constituted about 97% of the seed bank. Density and height of plants were higher in the middle marsh. Plant cover and number of branches were lowest in lower marsh and increased substantially in next zone, with no significant differences among other zones. Dry weight accumulation was highest in lower-middle marsh.

Introduction

Arthrocnemum macrostachyum (Moric.) C. Koch (Chenopodiaceae) (Syn. *Arthrocnemum indicum* L.) is a perennial, stem succulent halophyte found in the intertidal zone of the Arabian Sea at Karachi, Pakistan (Karim & Qadir, 1979). Gul & Khan (1994) found that population of *A. indicum* was subjected to spatial and temporal variation in soil salinity and soil moisture ranging from drought to flood levels. Vegetative growth of *A. macrostachyum* was related with change in soil salinity and although it produced a large number of seeds, recruitment through seeds was rare. Khan & Gul (1998) reported both morphological and physiological dimorphism in *A. indicum* seeds. *A macrostachyum* produces brown and black seeds with brown seeds heavier than black seeds. Arthrocnemum macrostachyum could be classified among the most salt tolerant species during the germination stage since brown seeds could germinate in up to 1000 mM NaCl. At lower temperature regimes salinity was less inhibitory to germination and about 70 to 86% recovery of germination was recorded when salt stress was removed after 20 days distilled water treatment. Khan *et al.*, (1998) showed that application of GA_3 and kinetin significantly alleviated the effect of salinity on germination while application of proline and betaine was not stimulatory. It seems that *A. macrostachyum* seeds have an enforced dormancy imposed by high salinity and temperature and when these stresses are removed seeds readily germinated.

Seed bank studies of coastal salt marshes from eastern and western North America demonstrated that the dominant perennial grass *Spartina* spp., did not maintain a persistent seed bank (Hopkins & Parker, 1984; Hartman, 1988). The size of the seed bank for coastal salt marshes varied from a low of 47 seeds m^{-2} in a Massachusetts salt marsh to 140,000 seeds m^{-2} in a Baltic salt marsh (Jerling, 1984; Hartman, 1988). British coastal salt marshes have shown that there were no persistent seed banks or only a small seed bank in the zonal communities (Milton, 1939; Jefferies *et al.*, 1981;

Hutching & Russell, 1989). Gulzar & Khan (1994) studied 6 different coastal communities located on the Karachi coast. The communities varied in inundation frequency which ranged from diurnal inundation to seasonal inundation. Seed bank of the species from communities with seasonal inundation was very small (30-260 seeds m^{-2}), however, communities with diurnal inundation had substantially higher seed bank (11,000 seeds m^{-2}). Aziz & Khan (1996) reported that seed banks of the *Cressa cretica* community (seasonal inundation) approaches 2500 seeds m^{-2} after they are dispersed and drops down to 500 seed m^{-2} a few months later. A number of hypotheses are suggested to explain the relatively small number of seeds found in many coastal marsh habitats; loss of seeds because of tidal abrasion (Hutching & Russell, 1985), environmental extremes beyond the range of tolerance (Ungar, 1991), and composition of above-ground vegetation and its seed production (Milton, 1939; Hutchings & Russell, 1989).

Tidal action appears to be the most important cause for the mortality, growth and survival of coastal population (Wiehe, 1935; Brereton, 1971), and this difference could lead to difference in phenology of halophytes like *Salicornia europaea* L. (Jefferies *et al.*, 1981). The variation in population characteristics of halophytes along salinity gradients are not yet well understood and only a few studies are available (Beeftink *et al.*, 1978; Jefferies *et al.*, 1979, 1981, 1983; Phillipupillai & Ungar, 1984; Khan & Ungar, 1986).

The present report describes the seed bank and demography of *A. macrostachyum* growing in a coastal salt marsh on the shore of Arabian Sea.

Materials and Methods

The study site is located in Manora creek near Sands Pit on the Karachi coast. This salt marsh is regularly inundated with seawater. The waterlogged lowest area was dominated by *Avicennia marina* followed by almost a pure population of *Arthrocnemum macrostachyum*.

The population was divided into 5 equal zones:

1. Upper marsh: the landward edge of the population with minimum seawater inundation (*Arthrocnemum macrostachyum, Limonium stocksii, Cressa cretica, Aeluropus lagopoides, Suaeda fruticosa, Atriplex griffithii*)
2. Upper-middle (*A. macrostachyum*)
3. Middle (*A. macrostachyum*)
4. Lower-middle (*A. macrostachyum*)
5. Lower (*A. macrostachyum*): next to *Avicennia marina*, which receive maximum inundation.

Ten soil cores (2.5 cm X 15 cm) were collected from each zone and seeds were sorted from soil samples with the help of binocular microscope and identified. Transects were laid across the population with 1 m^2 contiguous plots. Number of branches, plant height, plant cover, number of plants per quadrat and dry weight of leaves was recorded.

Results

There was a great variation in the size of the seed bank of *A. macrostachyum* from the upper to the lower marsh (Table 1). Seed banks of the lower zone had 2987 seed m^{-2}, while seed banks at the upper marsh had 141,509 seed m^{-2}. The community studied had almost pure population of *Arthrocnemum macrostachyum*. Few other halophytes dominating in nearby areas were present in the upper marsh. The seed bank reflected the vegetation pattern (Table 1). At the lower marsh the seed bank was represented only by *A. macrostachyum* and the number of species in the seed bank progressively increased towards the upper zone, from one in the lower zone to 6 species in the upper zone (Table 1).

Dry weight of leaves was highest in the lower-middle marsh (Fig. 1) and dry weight of the plants from all other zones were not significantly different from each other. Cover of the plants in lower marsh was about half in comparison to the cover of plants in all other zones, which were not significantly different from one another (Fig. 2). Maximum number of plants was found in the intermediate zone and the number declined on both extremes (Fig. 3).

Number of branches per plant increased from lower to middle marsh and then remained unchanged towards the upper marsh (Fig. 4). Plant height also peaked in the middle marsh (Fig. 5). Height of plants in the lower marsh was not significantly different from the height of plants present in the upper marsh.

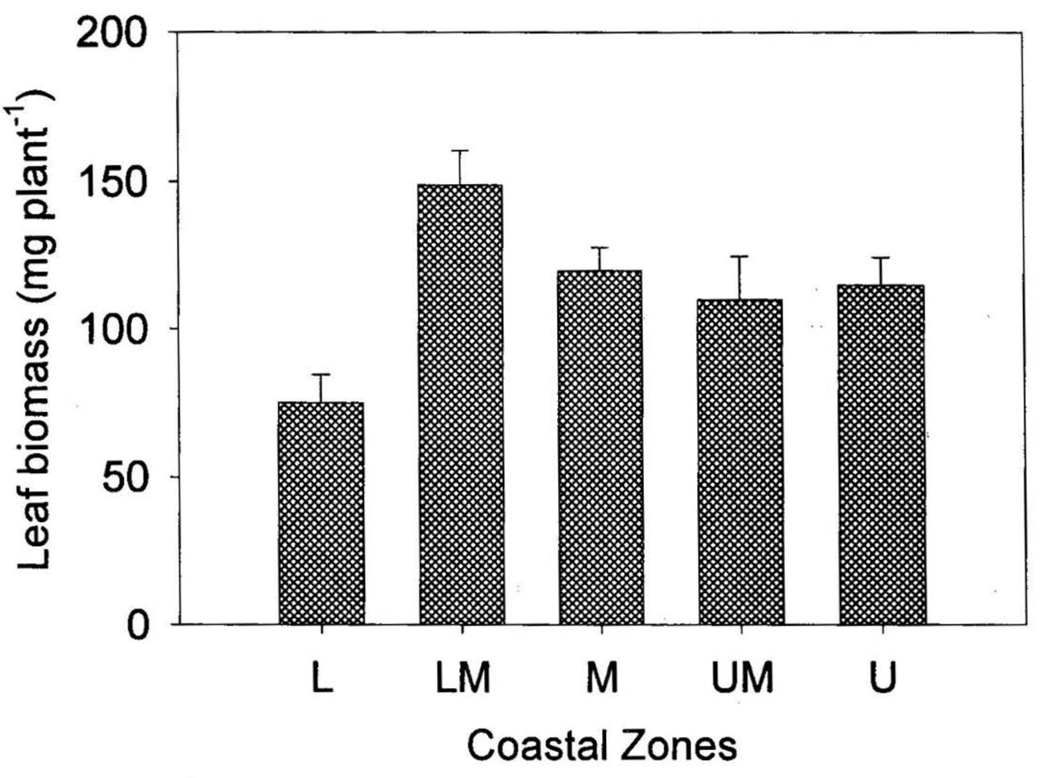

Fig.1. Leaf dry weight of *Arthrocnemum macrostachyum* plants collected from various coastal zones.

Table 1. Mean number of seeds from soil samples (seed m^{-2}) collected from different of *Arthrocnemum macrostachyum* population (± SE).

Species	Lower marsh	Lower-middle	Middle	Upper-middle	Upper
Aeluropus logopoides	0	0	0	314 ±64	628 ±165
Arthrocnemum machrostachyumum	2,987 ±345	3,144 ±210	62,890 ±2867	94,330 ±1543	141,509 ±2345
Atriplex griffithii	0	0	0	628 ±156	314 ±113
Cressa cretica	0	0	0	628 ±164	1572 ±87
Limonium stocksii	0	0	943 ±123	2201 ±201	2,201 ±187
Suaeda fruticosa	0	0	0	0	1257 ±324

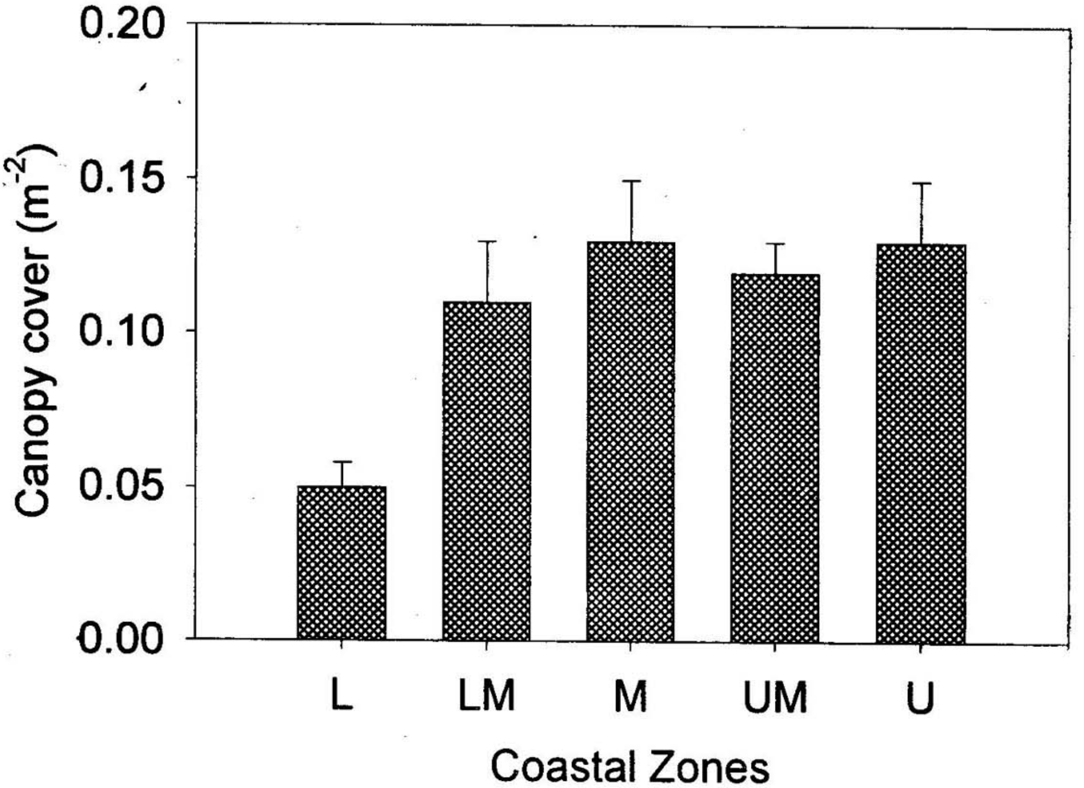

Fig.2. Canopy cover (m^2 plant cover/m^{-2} ground cover) of *Arthrocnemum macrostachyum* plants collected from various coastal zones.

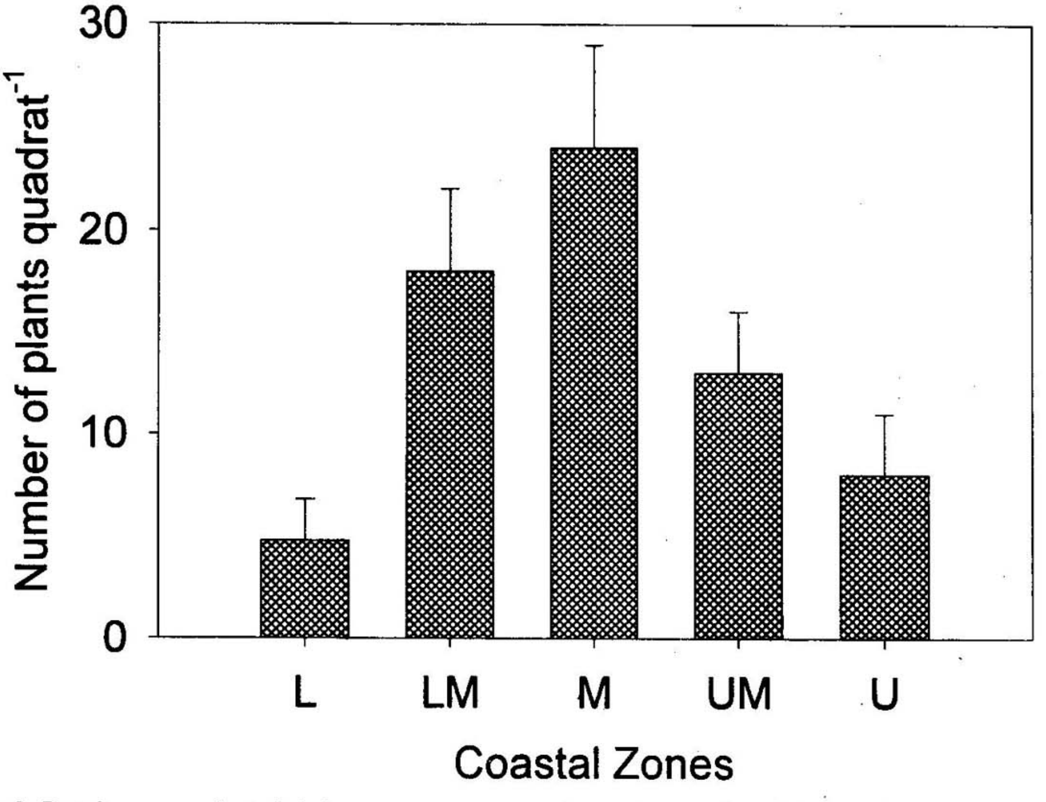

Fig.3. Density per quadrat of *Arthrocnemum macrostachyum* plants collected from various coastal zones.

Discussion

Arthrocnemum macrostachyum usually grows in the intertidal zone with varying degrees of inundation. The area close to the sea received diurnal inundation whereas the upper marsh was inundated during spring high tides, thus creating different zones varying in salinity and waterlogging. The area close to the sea will be less saline and more water logged in comparison to the upper marsh where salinity increased and soils moisture saturation levels decreased. Our data indicate that the subtropical Arabian Sea salt marsh located at Karachi, Pakistan does have a relatively large seed bank. Size of the seed bank varied with the level of inundation, increasing with an increase in inundation frequency.

Several researchers have reported either small seed banks or the complete lack of seed banks in Atlantic coastal marshes (Hartman, 1988). Some communities studied on Pacific coastal marshes may have large seed banks, while others will have a temporary or persistent seed bank (Josselyn & Pereż, 1981; Hopkins & Parker, 1984). In an area of tidal marsh restoration in California, Josselyn & Perez (1981) found that 92% of the seed bank (83,050 seed m^{-2}) was made up of *Spergularia marina*. *Spartina foliosa* was reported not to have a persistent seed bank in a community it dominated in San Francisco Bay salt marshes (Hopkins & Parker, 1984). In a zonal community dominated by *Salicornia virginica*, the seed bank in October contained 700 to 3175 seeds m^{-2}. The dominant species made up 96.7% of the seed bank and there was a high correlation between the seed bank and the species in plant community. Ungar & Woodell (1993) ran similarity indices to determine the relationship among communities

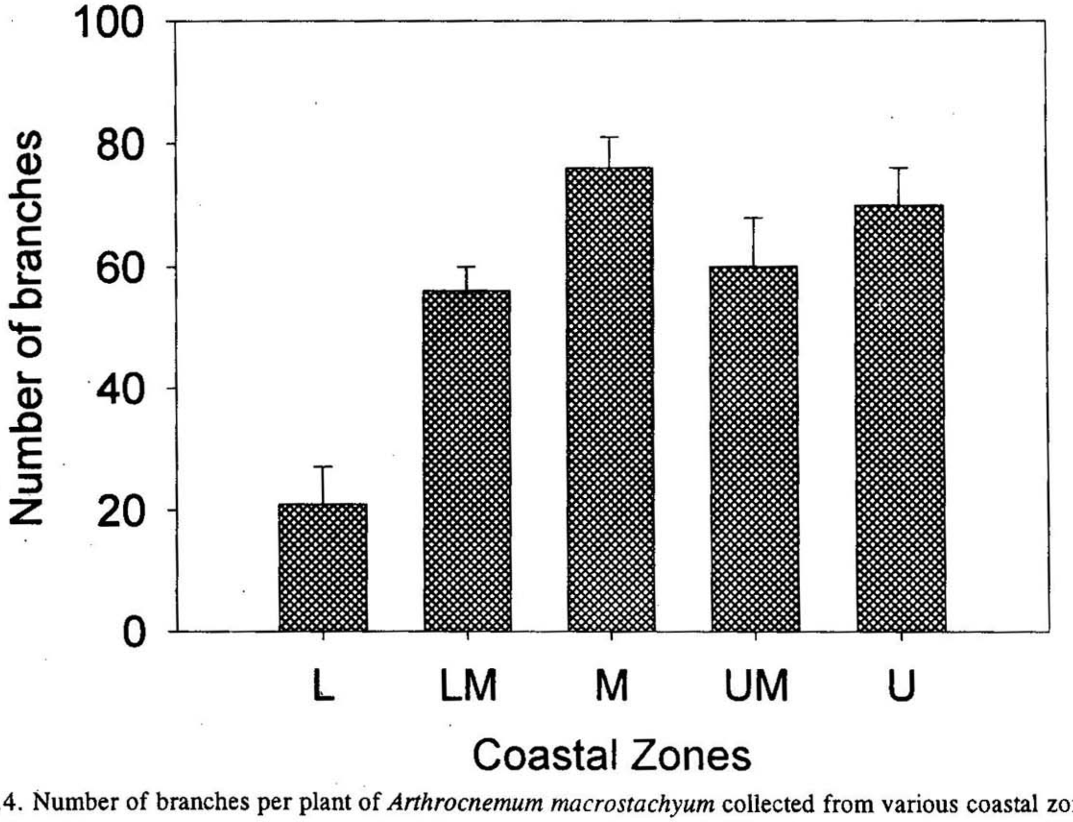

Fig.4. Number of branches per plant of *Arthrocnemum macrostachyum* collected from various coastal zones.

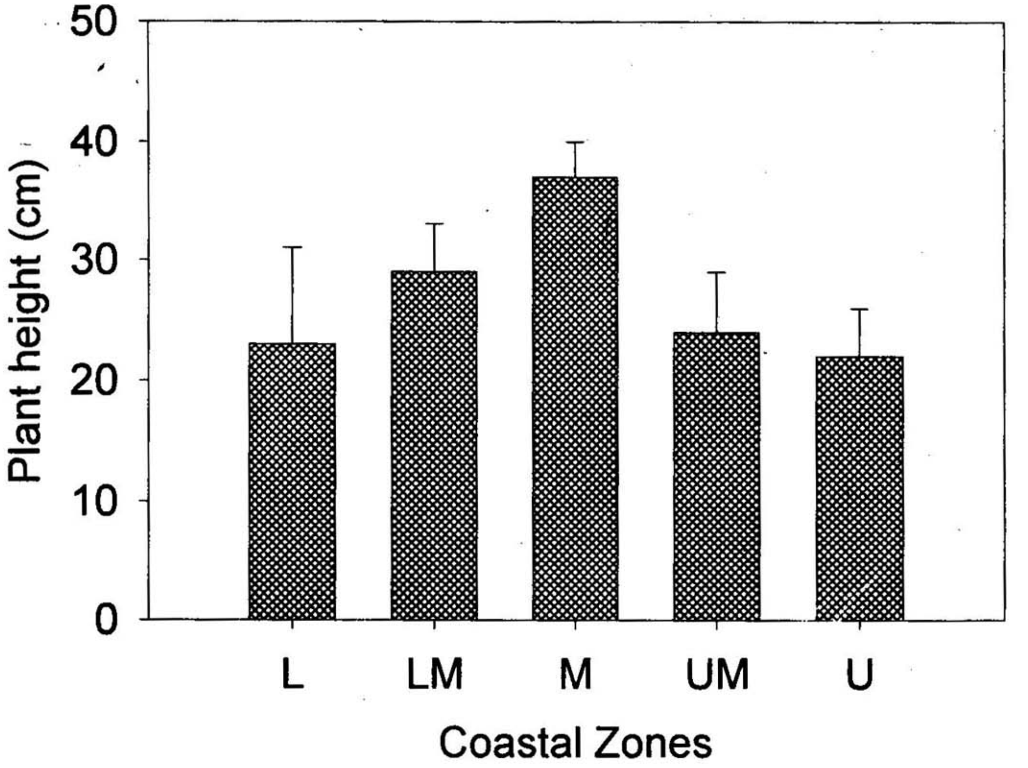

Fig.5. Height of *Arthrocnemum macrostachyum* plants collected from various coastal zones.

and their seed banks. The marsh community investigated were those dominated by *Salicornia europaea, Suaeda maritima, Puccinellia maritima, Halimione portulacoides, Spartina anglica* or areas dominated by a combination of these species. It was observed that there was a relatively low similarity index between the seed bank and above ground vegetation in some communities on both salt marshes. Similarity index values in annual dominated vegetation indicated a closer relationship between the seed bank and aboveground vegetation. Salt marsh communities dominated by perennial species often do not maintain a persistent seed bank of dominants (Ungar, 1991). *A macrostachyum* continues its life cycle through vegetative propagation. Hardly any seedlings were found during the last 5 years of continuous monitoring of the population. Why there is no recruitment through seeds is still a mystery. The salt marsh does have a large seed bank, and seeds are ready to germinate when temperature and salinity is reduced after monsoon rains (Khan & Gul, unpublished data). Most variation in physical factors across the marsh appeared to be due to elevational differences in tidal flooding (Bertness & Ellison, 1987). Substrate redox generally increases and substrate salinity generally decreases with increasing tidal height and decreased tidal flooding (Mendelssohn *et al.*, 1981). Growth of plants is inhibited by low substrate redox (Howes *et al.*, 1981; Mendelssohn *et al.*, 1981), and salinity (Linthurst & Seneca, 1980). Tidal flooding most likely influences many other important edaphic factors (Ponnamperuna, 1972; Chalmers, 1982). Population density and growth of *A. macrostachyum* varied with inundation gradient. Density and height of plants were highest in the zone of moderate salinity and flooding. Plant cover and number of branches were severely inhibited by flooding and reduction in flooding significantly improved the plant cover and number of branches. Increases in salinity had no effect on plant cover and branching.

Our study showed that coastal marshes in the intertidal zone of the Arabian Sea maintained a large persistent seed bank. The size of the seed bank increased from upper to lower marsh. The middle marsh with moderate salinity and inundation provided a better environment for growth of *A. macrostachyum* plants.

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