Pak.J.Bot., 31(1): 163-172, 1999.

EFFECT OF INTRASPECIFIC COMPETITION AND INUNDATION REGIME ON THE GROWTH OF *ARTHROCNEMUM MACROSTACHYUM* IN A COASTAL SWAMP IN KARACHI, PAKISTAN

BILQUEES GUL AND M. AJMAL KHAN

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

Abstract

Arthrocnemum macrostachyum is a stem succulent halophyte commonly found in the intertidal communities in the tropics and subtropics. The effect of density on the growth of a population of *A. macrostachyum* in various zones at the Arabian Sea coast was studied. Above ground biomass was low in lower swamp and a change in density has little affect in all zones. Below ground biomass showed a considerable reduction in the upper swamp in comparison to the middle and lower swamp. Height of the plant remained unaffected by density but was substantially reduced in lower swamp. Number of branches and basal area of the plants decreased with increasing density while middle swamp plants showed high basal area and branching.

Introduction

Tidal swamp communities are ideal for investigating questions of plant community dynamics and structure (Pidwirny, 1989). These communities are usually dominated by a few species that have adapted to the rigors of this environment (Zahran, 1977). Common to most tidal swamps is a zonal species pattern correlated to particular ranges of elevation and inundation frequency on the swamp (Vince & Snow, 1984). Most of the research work in tidal swamp habitats has centered on the way abiotic factors affected plant growth and species zonation where soil aeration (Burdick & Mendelssohn, 1987), salinity (Snow & Vince, 1984; Ewing *et al.*, 1989), inundation frequency (Disraeli & Fonda, 1979; Hutchinson, 1982), disturbance (Bertness & Ellison, 1987; Ellison, 1987), soil drainage (Mendelssohn & Seneca, 1980; Wiegert *et al.*, 1983), soil texture (Dawe & White, 1982; 1986), nutrient toxicity (Mendelssohn & McKee, 1988; Koch & Mendelssohn, 1989), and nutrient limitation (Valiela & Teal, 1974; Mendelssohn, 1979) have been suggested as important factors in controlling the occurrence of plant species in tidal swamp habitats. Besides the arrangement of the upper and lower limits of species distributions in tidal swamps may be controlled by interspecific plant competition (Snow & Vince, 1984; Dawson & Bliss, 1987). Studies that manipulated the densities of competing species has put forth the strongest suggestion for occurrence of competition in these habitats (Silander & Antonovics, 1982; Rozema *et al.*, 1988).

Intraspecific competition may influence the survival, growth, and fecundity of populations in saline habitats (Ungar, 1991). Halophytes may be morphologically plastic in their response to increased plant density but mortality is not directly correlated with density-dependent factors (Jefferies *et al.*, 1983; Ungar, 1987).

Mortality of halophytes growing in inland and coastal salt marshes is probably due to physical factors in the highly stressful environment such as flooding and high salinity rather than competition (Jefferies *et al.*, 1983; Ungar, 1987). Tidal action appears to be the most important cause for the mortality, growth and survival of coastal plants (Wiehe, 1935; Bererton, 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 the salinity gradient are not yet well understood and only a few studies are available (Jefferies *et al.*, 1979; 1981; 1983; Phillipupillai & Ungar, 1984; Ungar, 1983; Khan & Ungar, 1986; Gul & Khan, 1998).

Arthrocnemum macrostachyum (Moric) C. Koch (Chenopodiaceae) (Syn. *Arthrocnemum indicum* L.) is a stem-succulent perennial halophytic shrub, commonly found in tropical coastal salt swamps, which are frequently inundated with seawater (Sadek & El-Darier, 1995). Karim & Qadir (1979) described that *A. macrostachyum* is a low shrub that occurs in almost pure stands or rarely with other species like *Limonium stocksii*, *Cressa cretica, Aeluropus lagopoides* and *Suaeda monoica*. *Arthrocnemum macrostachyum* propagates itself primarily by vegetative means (rhizomes) flowering and seed set occur from April to May (Gul & Khan, 1998) and a large number of seeds is produced but recruitment from seed is rare. The present report describes the effect of intraspecific competition along the inundation gradient in an Arabian seashore coastal population of *Arthrocnemum macrostachyum*.

Materials and Methods

The study site is located in Manora Creek, near Sands Pit about 10 km from Karachi, Pakistan (24° 48' N, 65° 55' E) where mean ambient summer and winter temperatures are 36°C and 25°C, respectively. Rains are received during monsoon season, which extends from June to September. *Avicennia marina* dominated the areas submerged with seawater and from the *Avicennia marina* edge to mean high tide line, the 11 m^{-2} site is dominated by *Arthrocnemum macrostachyum*. Landward side, the various communities are dominated by *Atriplex griffithii, Suaeda fruticosa, Aeluropus lagopoides, Halopyrum mucronatum* and *Cressa cretica*. Flowering and seed set of *A. macrostachyum* occur from May to July. This lower swamp is inundated twice a day with seawater while upper swamp is inundated only during lunar high tide. The community along the transect was divided into three equal zones: 1. Lower swamp (adjacent to *Avicennia marina*, which receives maximum inundation.), 2. Middle, and 3. Upper (landward edge of the population with minimum inundation of seawater).

A series of quadrats were established to determine the effect of competition on the growth of plants present in various zones. Ten plots (100 x 100 cm) each having thinned to a density of 1, 4, and 10 plants/quadrat were established in each zone. Plants were harvested at the end of the growing season. The above ground and below ground biomass, number of branches, plant height, plant cover and number of plants per quadrat were recorded. The results were analyzed using three way ANOVA. A Bonferroni test was carried out to determine if significant ($P<0.05$) differences occurred between individual treatments (Anon., 1996).

Results

A three way ANOVA indicated a significant ($P < 0.0001$) effect of time of harvest on the above ground biomass of *A. macrostachyum* whereas density, site, and all interactions were non-significant in affecting above ground biomass (Table 1). The change in density had no significant effect on the above ground biomass of *A. macrostachyum* both at early and late vegetative stages (Fig. 1). However, above ground biomass in the lower swamp was lower at all density but there was no significant difference between the above ground biomass of upper and middle swamp (Fig. 1).

A three way ANOVA indicated a significant ($P<0.0001$) effects of density, site, time of harvest and their interactions in affecting below ground biomass of *A. macrostachyum* (Table 1). Below ground biomass was significantly lower at upper swamp in all density and age treatments (Fig. 2). However, there was no significant

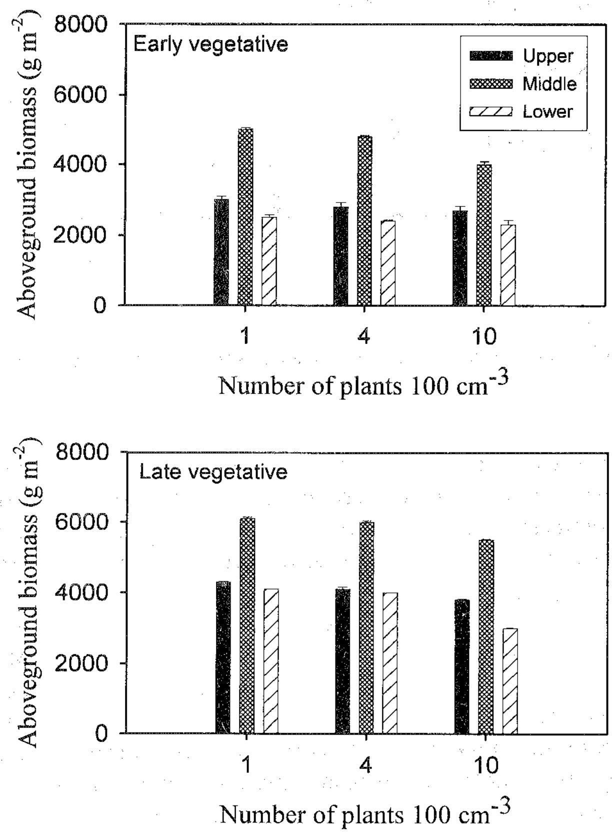

Fig.1. Above ground biomass of early and late vegetative *Arthrocnemum macrostachyum* plants collected from various coastal zones.

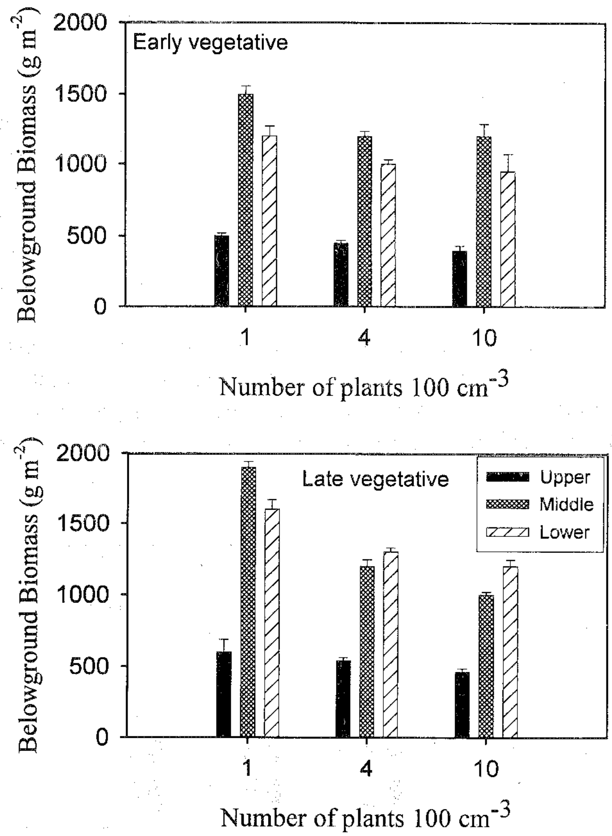

Fig.2. Below ground biomass of early and late vegetative *Arthrocnemum macrostachyum* plants collected from various coastal zones.

difference between below ground biomass of middle and lower zone plants. There was a significant density effect on below ground biomass where plots with one plant m^{-2} have the higher biomass (Fig. 2), whereas, no significant differences between middle and lower salt swamp was found. This difference was more pronounced in the late vegetative stage.

A three way ANOVA indicated a significant ($P < 0.0001$) effect of density and site and their interaction on the number of branches in *A. macrostachyum* whereas time of harvest and all other interactions were not significant in affecting the number of branches (Table 1). Number of branches both at early and late vegetative stages and at all densities were significantly ($P<0.05$, Bonferroni test) higher in plants found in the middle zone (Fig. 3). Middle swamp plants showed higher branching but it decreased with increasing density, as it did in the other zones (Fig. 3).

A three way ANOVA showed a significant ($P<0.0001$) effect of density and site and except for density and time all the interactions significantly affected the cover of

Table 1. Result of three way analysis of variance of characteristics by Density (D), Site (S), Time of harvest (T) treatments.

	Independent variable						
Dependent variable	D	S	T	SxD	DxT	SxT	DxTxS
Above ground biomass	$1^{n.s}$	$1^{n.s}$	8^{***}	$1.1^{n.s.}$	$1.5^{n.s}$	$1^{n.s}$	$0.8^{n.s.}$
Belowground biomass	6^{***}	90^{***}	81^{**}	10^{***}	14^{**}	13^{***}	4^{***}
Number of branches	4^{*}	84^{***}	$0.005^{n.s}$	7^{***}	$0.5^{n.s.}$	$0.03^{n.s.}$	$0.7^{n.s.}$
Cover	18^{**}	10^{***}	$1^{n.s.}$	4^{**}	$1^{n.s.}$	13^{***}	8^{***}
Height	3^{*}	27^{***}	7^{**}	3^{*}	$0.7^{n.s.}$	$1^{n.s.}$	$0.4^{n.s.}$

Note: Numbers represent F values: $^{n.s.}$ = not significant, * = $P<0.05$, ** = $P < 0.01$; *** = $P<0.001$.

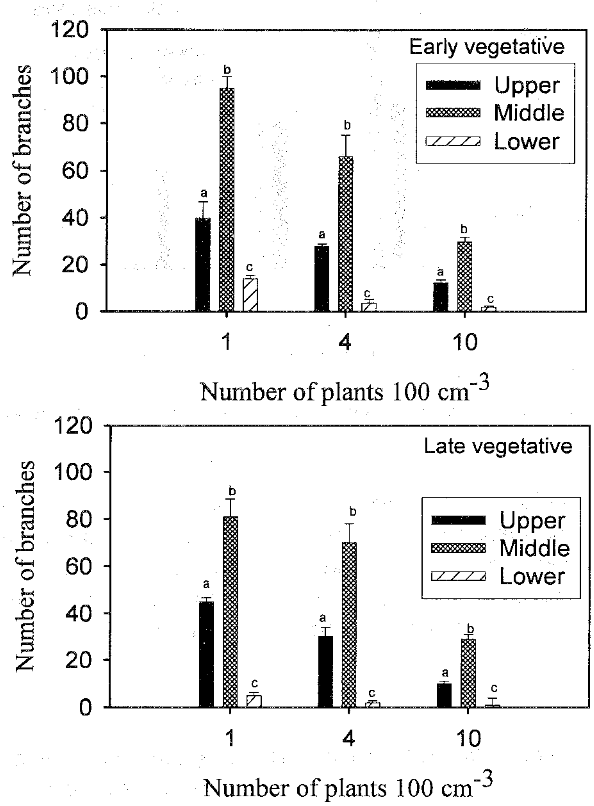

Fig.3. Number of branches per plant of early and late vegetative *Arthrocnemum macrostachyum* plants collected from various coastal zones.

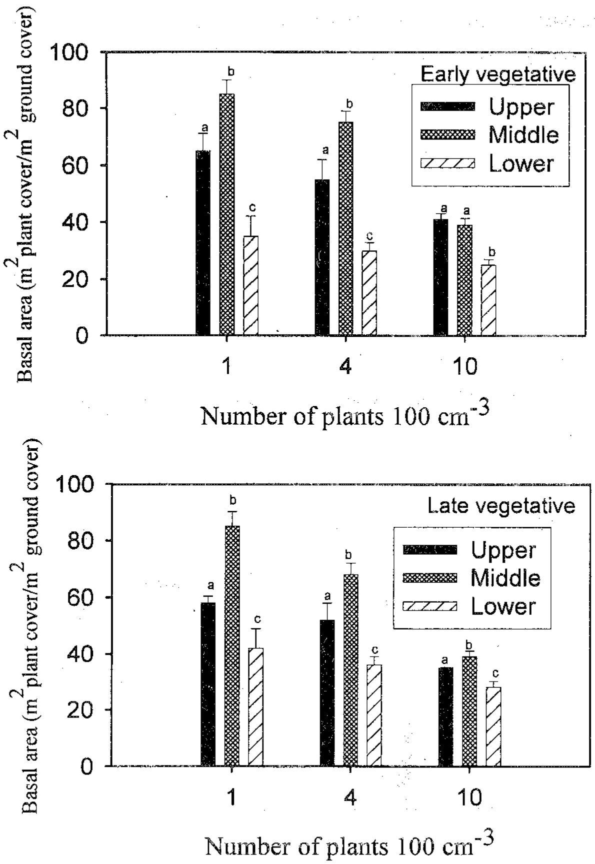

Fig.4. Basal area (m^2 plant cover/m^{-2} ground cover) of early and late vegetative *Arthrocnemum macrostachyum* plants collected from various coastal zones.

A. macrostachyum (Table 1). At lower densities the basal area of the shrub was higher in middle swamp and there were no significant differences between basal areas in the upper and lower zones at both growth stages (Fig. 4). Change in density had little effect on the height of plants in all zones (Fig. 5). However, height of plants in lower swamp was significantly ($P<0.05$, Bonferroni test) lower at all densities.

Discussion

Arthrocnemum macrostachyum usually grows in the intertidal zone with varying degrees of inundation (Gul, 1993). The area close to the sea received two inundations every day whereas, the upper swamp was only inundated during high tides, thus creating a gradient in which salinity and water logging varied (Gul & Khan, 1998). The lower swamp zone would be less saline and more water logged in comparison to the upper swamp where salinity is increased due to evaporation and soil moisture saturation

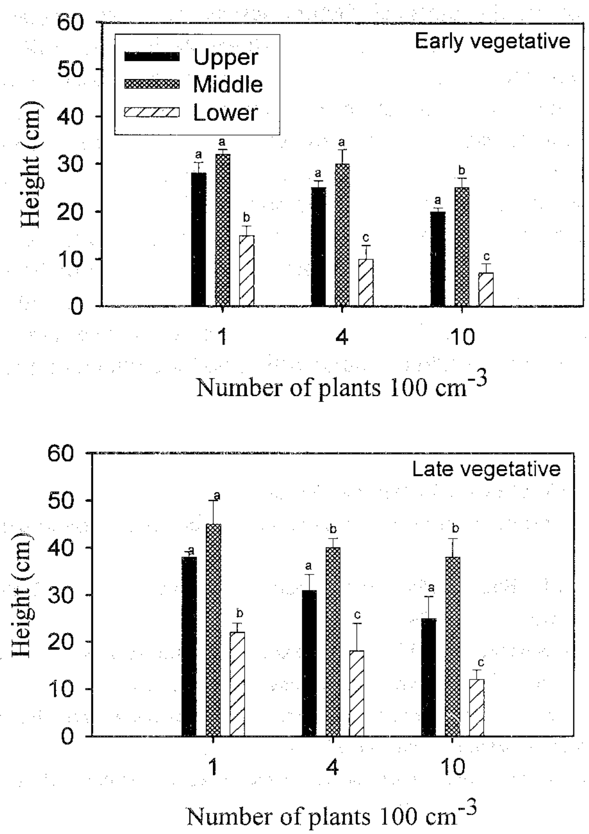

Fig.5. Plant height of early and late vegetative *Arthrocnemum macrostachyum* plants collected from various coastal zones.

is decreased. Our data indicated a great deal of variation in the growth and morphology in the individuals of *A. macrostachyum* growing in different zones of an Arabian Sea coastal salt swamp. Populations growing in the upper salt swamp have high above ground biomass, plant height and basal areas. Plants grow better in middle swamp due to low salinity and inundation regimes. Above ground biomass, height of plants, basal area and number of branching were optimal at this zone. Plants showed poor growth in lower swamp exposed to diurnal inundation where it produced a significantly higher below ground biomass. Increase in density had little effect on the dry weight of plants, however, basal area and number of branches decreased with increase in density.

Intraspecific competition may affect the survival, growth and fecundity of population in saline habitats (Ungar, 1991). Growth inhibition and mortality in inland and coastal swamps was probably due to physical factors in the highly stressful salt swamp environment, such as flooding, drought and high salinity rather than competition (Jefferies *et al.*, 1983; Ungar, 1987).

Most variation in the physical factors across the swamp appeared to be due to elevational differences in tidal flooding (Bertness & Ellison, 1987). Substrate redox generally increased and substrate salinity generally decreased with increasing tidal height and decreased tidal flooding (Mendelssohn *et al.*, 1986). Growth of the plants are inhibited by low substrate redox (Howes *et al.*, 1981; Mendelssohn *et al.*, 1986) and salinity (Linthurst & Seneca, 1980). Tidal flooding most likely influences many other important edaphic factors (Ponnamperuna, 1972; Chalmers, 1982). Population growth of *A. macrostachyum* varied with inundation gradient. Density and height of plant were highest in the zone with moderate salinity and flooding. Plant cover and number of branches were severely inhibited by flooding and its reduction significantly improved the plant cover and number of branches. *Arthrocnemum macrostachyum* population grows better in middle swamp with moderate inundation and lower salinity.

References

Anonymous, 1996. SPSS: SPSS 7.0 for Windows 95. SPSS Inc., USA.

Bererton, A.J. 1971. The structure of the species populations in the initial stages of salt-swamp succession. *J. Ecol.*, 59: 321-338.

Bertness, M.D. and M.D. Ellison. 1987. Determinants of pattern in a New England salt swamp plant community. *Ecol. Monog.*, 57: 129-147.

Burdick, D.M. and I.A. Mendelssohn. 1987. Water logging response in dune, swale and swamp population of *Spartina patens* under field conditions. *Oecologia*, 74: 321-329.

Chalmers, A.G. 1982. Soil dynamics and productivity of *Spartina alterniflora*. In: *Estuarine comparisons* (Ed.) V.S. Kennedy, Academic Press, pp. 231-242.

Dawe, N.K. and E.R. White. 1982. Some aspects of the vegetation ecology of the little Qualicum River estuary, British Columbia. *Can. J. Bot.*, 6o: 1447-1460.

Dawe, N.K. and E.R. White. 1986. Some aspects of the vegetation ecology of the Nanoose-Bonell estuary, Vancouver Island, British Columbia. *Can. J. Bot.*, 64: 27-34.

Dawson, T.E. and L.C. Bliss. 1987. Species patterns, edaphic characteristics and plant water potential in a high-arctic brackish swamp. *Can. J. Bot.*, 65: 863-868.

Disraeli, D.J. and R.W. Fonda. 1979. Gradient analysis of the vegetation in a brackish swamp in Bellingham Bay, Washington. *Can. J. Bot.*, 57: 465-475.

Ellison, M.A. 1987. Effects of competition, disturbance and herbivory on *Salicornia europaea*. *Ecology*, 68: 576-586.

Ewing, K., J.C. Earle, B. Piccinin and K.A. Kershaw. 1989. Vegetation patterns in James Bay coastal swamps. II. Physiological adaptation to salt-induced water stress in three halophytic graminoids. *Can. J. Bot.*, 67: 521-528.

Gul, B. 1993. *Demography, ecophysiology and seed bank dynamics of Arthrocnemum indicum*. M. Sc. Thesis, University of Karachi, Karachi. pp 143.

Gul, B. and M. A. Khan. 1998. Population characteristics of the coastal halophyte *Arthrocnemum macrostachyum*. *Pak. J. Bot.*, 30: 189-197.

Howes, B.L., R.W. Howarth, J.M. Teal and I. Valiela. 1981. Oxidation-reduction potential in a salt marsh: spatial patterns and interactions with primary production. *Limnol. Oceanog.*, 26: 350-360.

Hutchinson, I. 1982. Vegetation-environment relations in a brackish swamp, Lulu Island, Richmond, B.C. *Can. J. Bot.*, 60: 452-462.

Jefferies, R.L., A.J. Davy and J. Rudmick. 1979. The growth strategies of coastal halophytes. In: *Ecological processes in coastal environments*. (Eds.) R.L. Jefferies, & A.J. Davy, Blackwell, Oxford, pp. 243-268.

Jefferies, R.L., A. J. Davy and J. Rudmick. 1981. Population biology of the salt-swamp annual *Salicornia europaea* agg. *J. Ecol.*, 69: 17-31.

Jefferies, R.L., A. Jensen and D. Bazely. 1983. The biology of the annual *Salicornia europaea* agg., at the limits of its range in Hudson Bay. *Can. J. Bot.*, 61: 762-773.

Karim, A. and S.A. Qadir. 1979. Phytosociological studies of the coastal swamps of Karachi. *Bangladesh J. Bot.*, 4: 89-98.

Khan, M. A. and I. A. Ungar. 1986. Life history and population dynamics of *Atriplex triangularis*. *Vegetatio*, 66: 17-25.

Koch, M.S. and I.A. Mendelssohn. 1989. Sulphide as a phytotoxin: differential responses in two swamp species. *J. Ecol.*, 77: 565-578.

Linthurst, R.A. and E.D. Seneca. 1980. The effects of standing water and drainage potential on the *Spartina alterniflora- substrate* complex in a North Carolina salt marsh. *Estuarine and Coast Mar. Sci.*, 11: 41-52

Mendelssohn, I.A. 1979. Nitrogen metabolism in the height forms of *Spartina alterniflora* in North Carolina. *Ecology*, 60: 574-584.

Mendelssohn, I.A., and M.L. McKee.1988. *Spartina alterniflora* die-back in Louisiana: time-course investigation of soil water logging effects. *J. Ecol.*, 76: 509-521.

Mendelssohn, I.A., and E.D. Seneca. 1980. Influence of soil drainage on the growth of salt swamp grass *Spartina alterniflora* in North Carolina. Estuarine Coast. *Mar. Sci.*, 11: 27-40.

Mendelssohn, I.A., M. L. McKee and W. H. Patrick. 1986. Oxygen deficiency in *Spartina alterniflora* roots: metabolic adaptation to anoxia. *Science*, 214: 439-441.

Philipupillai, J. and I.A. Ungar. 1984. The effect of seed dimorphism on the germination and survival of *Salicornia europaea* L., populations. *Amer. J. Bot.*, 71: 542-549.

Pidwirny, M.J. 1989. Plant zonation in a brackish tidal swamp: descriptive verification of resource-based competition and community structure. *Can. J. Bot.*, 68: 1689-1697.

Ponnamperuna, F.N. 1972. The chemistry of submerged soils. *Adv. Agron.*, 24: 29-96.

Rozema, J., M.C.T. Scholten, P.A. Blaauw, and J. Diggelen. 1988. Distribution limits and physiological tolerances with particular reference to the salt swamp environment. In: *Plant Population Ecology*. (Eds.) A.J. Davy, M.J. Hutchings and A.R. Watkinson. Blackwell Scientific Publications, Oxford. Pp. 137-164.

Sadek, L.A. and S.M. El-Darier. 1995. Cyclic vegetational change and pattern in a community of *Arthrocnemum macrostachyum* in Mediterranean coastal desert of Egypt. *J. Arid Environ.*, 31: 67-76.

Silander, J.A. and J. Antonovics. 1982. Analysis of interspecific interactions in a coastal plant community-a perturbation approach. *Nature*, 298: 557-560.

Snow, A.A. and S.W. Vince. 1984. Plant zonation in an Alskan salt swamp. II. An experimental study of the role of edaphic conditions. *J. Ecol.*, 72: 669-684.

Ungar, I.A. 1983. Autecological studies with *Atriplex triangularis* Willdenow. In: *Proceeding Symposium on the biology of Atriplex and related chenopods*. (Eds.) A.R. Tiedeman, E.D. McArthur, H.C. Stutz, R. Stevens and K.L. Johnson. May 2-6, Provo, Utah Gen. Tech. Rep. INT-172, Ogden, UT: Dept. of Agric., Forest Service, Intermountain Forest and Range Experiment Station; 309 pp.

Ungar, I. A. 1987. Population characteristics, growth, and survival of the halophyte *Salicornia europaea*. *Ecology*, 68: 569-575.

Ungar, I.A. 1991. *Ecophysiology of Vascular Halophytes*. CRC Press, Boca Raton, FL.

Valiela, I. and J.M. Teal. 1974. Nutrient limitation in salt swamp vegetation. In: *Ecology of halophytes*. (Eds.) R. J. Reimold and W.H. Queens. Academic Press, New York. Pp. 547-563.

Vince, S.W. and A.A. Snow. 1984. Plant zonation in an Alaskan salt swamp. I. Distribution, abundance and environmental factors. *J. Ecol.*, 72: 651-667.

Wiegert, R.G., A.G. Chalmers and P.F. Anderson. 1983. Productivity gradients in salt swamps: the response of *Spartina alterniflora* to experimentally manipulated soil water movement. *Oikos*, 41: 1-6.

Wiehe, P.O. 1935. A quantitative study of the influence of tide upon populations of *Salicornia europaea*. *J. Ecol.*, 23: 323-333.

Zahran, M.A. 1977. Africa wet formations of the African Red Sea coast. In: *Ecosystem of the world. 1. Wet coastal ecosystems*. (Ed.) V.J. Chapman, New York: Elsevier. pp. 215-231.

(Received for publication 2 January 1999)