***Pak. J. Bot.*, 41(6): 2883-2892, 2009.**

SEASONAL VARIATION IN PRODUCTIVITY OF *CRESSA CRETICA* FROM COASTAL POPULATION ALONG THE ARABIAN SEA

FARHAT AGHA

DA Degree College for Women, Phase 7 (ext), Defense Housing Authority, Karachi-76000, Pakistan

Abstract

The productivity of *Cressa cretica* was studied for two years at monthly intervals in a coastal population located at Gizri Creek, south of Karachi, Pakistan. *Cressa cretica* showed variation in productivity in response to environmental factors. Net productivity and aboveground biomass were higher during the brief winter in comparison to summer which also varied between the two study years. Belowground biomass was much lower than the aboveground biomass but both followed similar seasonal trends. Increase in standing crop biomass and aboveground dead biomass also varied considerably. The highest net productivity in *Cressa cretica* was 0.18 g $m^{-2}d^{-1}$ in January. Electrical conductivity of shoots showed two peaks during the year 1997-1998 and gradually declined after October, while belowground parts showed little variation both within and between the years at around <10 dS m^{-1} except for high values of 22 dS m^{-1} in June 1997-98. Sodium was much higher followed by Cl^- and K^+ while Ca^+ and Mg^{2+} were very low. Similar ion patterns were found in roots. *Cressa cretica* could be a useful sand dune stabilizer along the coast which has potential for increased productivity under seawater irrigation.

Introduction

Productivity is one of the major factors in the maintenance of biological diversity as a source of food and other products necessary for heterotrophs particularly human beings (Lieth, 1972). A scarcity of fresh water due to increasing consumption by human population and inefficient utilization for the agricultural production is the main impediment leads to secondary salinization of prime agricultural lands. Increase in soil salinity causes a progressive decrease in the productivity to a level where growth of non-halophytes is not possible. UNEP estimates that 50% of agricultural land is salt stressed (Boland *et al*., 1996) in the arid and semiarid regions of the world which is a serious threat limiting crop production (Gheyi, 2000; Munns, 2002).

Cultivation of halophytic crops with tolerance to high salinity can be an option to utilize saline soils (Khan & Ungar, 1995; Glenn & Brown, 1999; Hamdy *et al*., 1999; Lieth *et al*., 1999). Halophytes could help in utilizing saline wasteland for conventional agricultural crops. Pure populations of halophytes appear to be distributed along the inundation gradient and productivity from low to upper marsh varies significantly. Coastal areas that are not inundated daily with seawater have rapid salinity build up due to the high rate of evapo-transpiration (Marcum & Murdoch, 1994; Khan *et al*., 1999).

Over a broad range of vegetation types, aboveground net primary productivity (ANPP) is strongly increased with precipitation, temperature and evapo-transpiration (Irlandi *et al*., 2001; Santos & Esteves, 2002; Lagergran *et al*., 2005). Species composition, vegetation physiognomy, and biomass also change with rainfall and temperature along regional geographic gradients (Laclan *et al*., 2002). Since community and ecosystem properties often vary, the effects of species composition and physiognomy on net primary productivity are often difficult to separate from the effects of climate (Yahdjian & Sala, 2006; Santos & Esteves 2002; Ronzhong *et al*., 2000; Jobbagy *et al*., 2002).

There are few studies on the belowground production of the material to compare with aboveground leaf production (Kenworthy & Thayer, 1984). In many communities (e.g., *Psoidonia*, *Zostera* and *Thalassia*) belowground biomass is 50-90% while in others it is only 20% (Hillman *et al*., 1989). Paling & McComb (2000) reported belowground production at around 16% of the aboveground in sea grasses. The rate of rhizome growth for *Psoidonia austrails* is more than *P. sinnosa* and this difference in productivity is because of the differences in depth of underground parts (Paling & McComb, 2000). Productivity pattern in *Caulerpa taxifolia* was relatively high throughout the year in different biotypes (Thibaut *et al*., 2004).

Cressa cretica is abundant along the sea-coast of Sindh and protects soil from wind erosion besides being grazed by animals. The present study was conducted to determine the seasonal variation in productivity of *Cressa cretica* under natural conditions.

Materials and Methods

The productivity of *Cressa cretica* was studied for two years from May 1997 to April 1999. The study site is located at Gizri Ceek, Karachi along the Arabian Sea coast.

Two plots with three quadrats (0.5 m^2) were selected randomly every first week of each month for two years. In plot # 1 equal sized mature plants were clipped close to the soil surface and separated into living and dead parts. Litter remaining on the surface was collected separately in plastic bags. Soil was collected from the root zone in each quadrat at a depth of maximum root penetration (approx. 30 cm). All belowground material (root) was collected by washing the soil with water with a 2 mm sieve. In plot # 2 only dead shoot material was removed and stored, living shoot material was tagged and harvested after one month. The plants were harvested and growth parameters i.e., fresh weight, dry weight, root length and shoot length were recorded. Dead material was separated from the living and weighed. Soil fresh weight and oven dry (80° C for 24 h) weights were noted.

Ion analyses and electrical conductivity of plant samples: Hot water extract of plant samples were prepared with 0.5 g plant material boiled in 10 ml distilled water in sealed test tubes for 2 h using water bath. The extract was cooled and filtered using Whatman No. 1 filter paper. The dilutions were made with deionized distilled water for ion analysis. Sodium and K^+ ion were measured with Ion 85 Ion analyzer (Radiometer, Copenhagen). Electrical conductivity was noted with the help of CDM 83 Conductivity meter (Radiometer, Copenhagen).

Electrical conductivity of soil samples: Soil samples were collected from 0-15 cm and 15-30 cm depths. Soil extracts (1:10) were made by dissolving 5 g soil in 50 ml distilled water and filtered using Whatman No 1 paper. Electrical conductivity was measured by CDM 83 conductivity meter (Radiometer Copenhagen).

Electrical conductivity for plant samples: Ground plant material (0.5 g) was boiled in 10 ml distilled water for 2 h at 90°C using a dry heat bath. The extract was cooled and filtered with Whatman No. 1 filter paper, diluted with distilled water for EC measurements with the help of conductivity meter. Data for conductivity were analyzed using ANOVA to determine if significant differences ($p<0.05$) occurred between treatments (Anon., 1996).

Table 1. Seasonal variation in soil conductivity (dSm^{-1}) at 15cm and 30cm depth in *Cressa cretica* community.

Months	1997-1998		1998-1999	
	15 cm	30cm	15 cm	30cm
May	0.58 ± 0.00	1.12 ± 0.24	4.24 ± 0.24	5.32 ± 0.24
June	1.4 ± 0.10	0.64 ± 0.18	3.74 ± 0.155	2.98 ± 0.22
July	2.4 ± 0.19	3.3 ± 0.23	2.18 ± 0.28	3.03 ± 0.24
August	2.98 ± 0.19	2.96 ± 0.23	1.75 ± 0.04	2.58 ± 0.17
September	3.84 ± 0.18	6.37 ± 0.25	2.34 ± 0.27	3.11 ± 0..26
October	5.09 ± 0.23	5.09 ± 0.13	1.85 ± 0.09	2.56 ± 0.21
November	2.57 ± 0.25	3.79 ± 0.24	3.56 ± 0.24	3.21 ± 0.29
December	2.4 ± 0.26	2.42 ± 0.24	4.49 ± 0.32	4.21 ± 0.21
January	3.78 ± 0.26	4.69 ± 0.23	3.79 ± 0.16	4.15 ± 0.26
February	3.85 ± 0.26	4.65 ± 0.22	2.25 ± 0.28	3.14 ± 0.29
March	3.67 ± 0.22	4.62 ± 0.23	1.23 ± 0.6	1.23 ± 0.06

Results

The average precipitation during the study was less than 35 mm however, it was relatively higher during the year one with mostly during the monsoon (Fig. 1). The following year received sporadic rainfall which was well below the average values of the region and in 1999 there was no rain at all (Fig. 1). Soil electrical conductivity (Table 1) was generally lower in year one than in year two particularly during the monsoon period. The net productivity was higher during 1998-1999 than in the 1997-1998. It was low from May to October and peaked in December (1997-1998) declining again in January during both years (Fig. 2). Aboveground biomass was also higher in 1998-99 (August and November) and ranged from 1-34 g m^{-2} (September) in comparison to 0.6-20 g m^{-2} in 1997-98 (Fig. 3). Belowground biomass was much lower and followed similar trends and peaked in September of 1997-98 and July and February of 1998-99 (Fig. 4). Standing crop biomass had a higher rate of increase in June declining substantially in July and August and showed an increase again after August reaching higher values in October (Fig. 5). Increase in standing crop biomass followed similar patterns between the two years except for higher values during June 1997 (2.4 g m^{-2}) and October 1997 (1.8 g m^{-2}). Above ground dead biomass varied significantly between the years except for the period from May to July and showed little variation during 1997-1998. However, during the next season there were considerable variations in biomass production showing two peaks in September – October (~3.5 g m^{-2}), and still higher values from January–April (~5.5 g m^{-2}) (Fig. 6).

Electrical conductivity of below ground parts showed lesser variation both within and between the two years at around <10 dS m^{-1} except for a couple of months and peak values in June in year one (Fig. 7). Shoot ion concentration during both the seasons varied a little and had more or less unchanged throughout the season (Fig. 8). Shoot sodium was much higher followed by Cl^- and K^+ while Ca^+ and Mg^{2+} were very low. Similar ion distribution patterns were found in roots (Fig. 9) Soil pH in the two study years 1997-98 and 1998-99 was generally basic (~8) and did not vary considerably between study years. However, it was slightly more basic in the deeper soil at 30 cm depth.

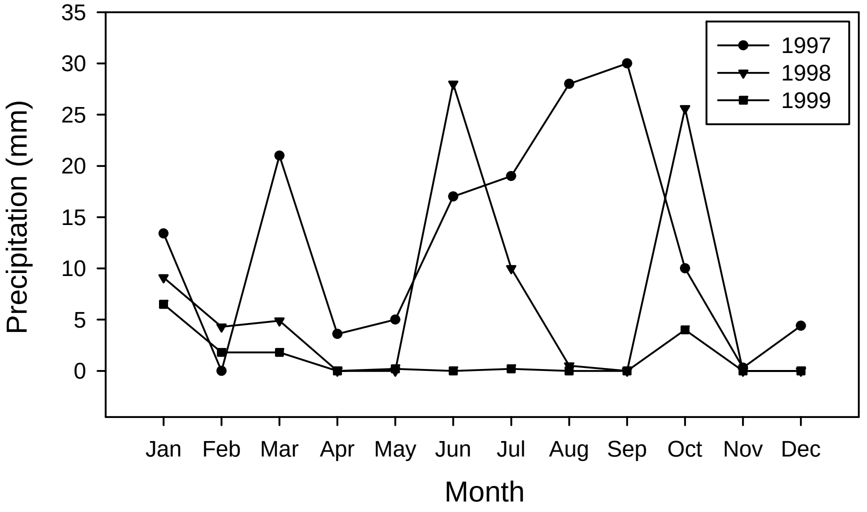

Fig. 1. Seasonal variation in rainfall near the study area at Clifton, Karachi along the Arabian sea coast over a three year period.

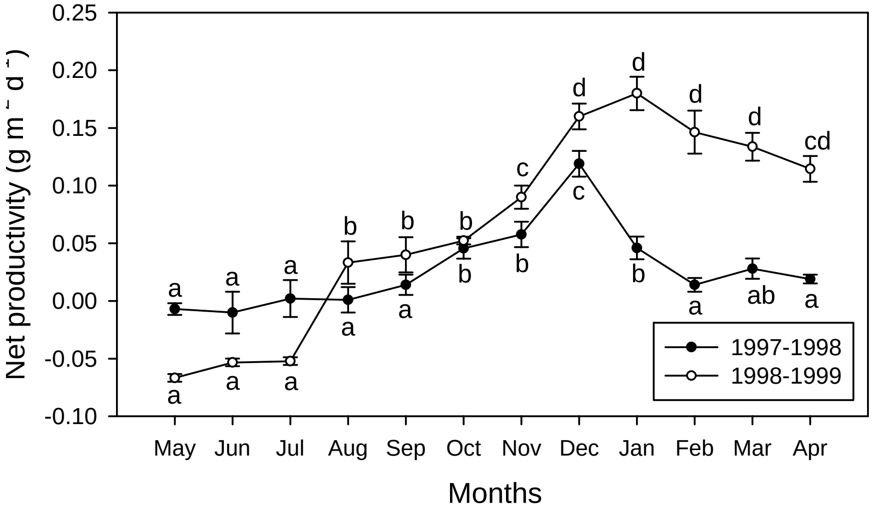

Fig. 2. Seasonal variation in net productivity (g m^{-2} day^{-1}) of *Cressa cretica*. Different letters for each year represent significant ($p<0.05$) differences between months (Bonferroni test).

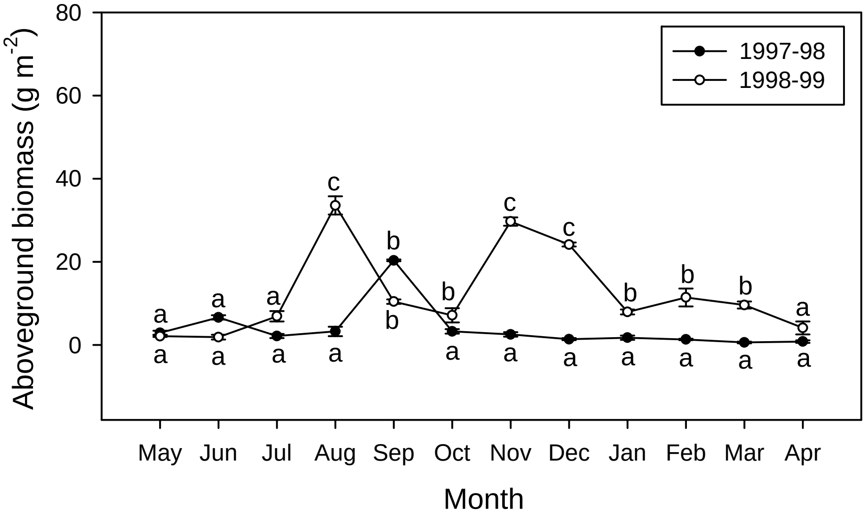

Fig. 3. Seasonal variation in above ground biomass (g m^{-1}) of *Cressa cretica*. Different letters for each year represent significant ($p<0.05$) differences between months (Bonferroni test).

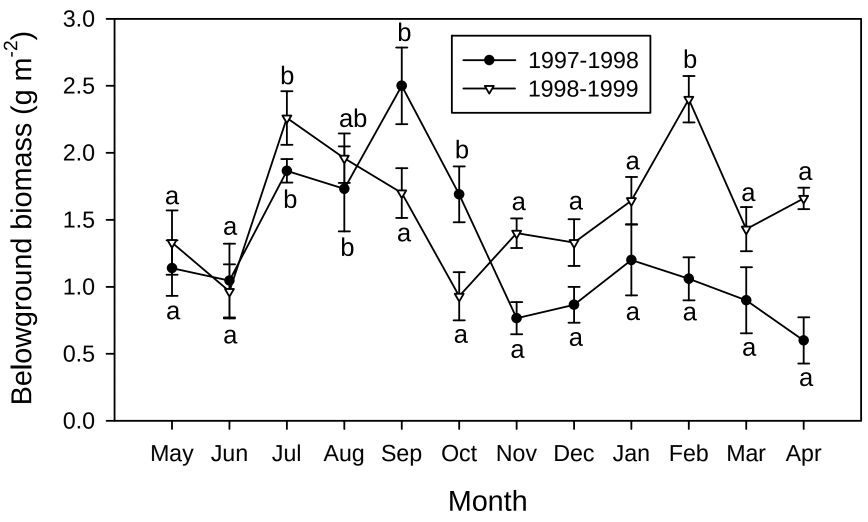

Fig. 4. Seasonal variation in belowground biomass (g m^{-2}) of *Cressa cretica*. Different letters for each year represent significant (p<0.05) differences between months (Bonferroni test).

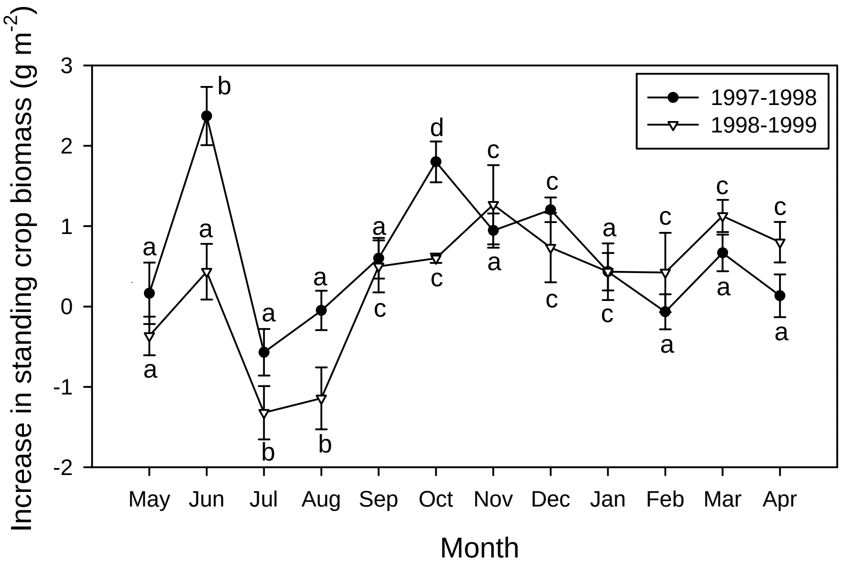

Fig. 5. Seasonal increase in standing crop biomass (g m^{-2}) of *Cressa cretica*. Different letters for each year represent significant (p<0.05) differences between months (Bonferroni test).

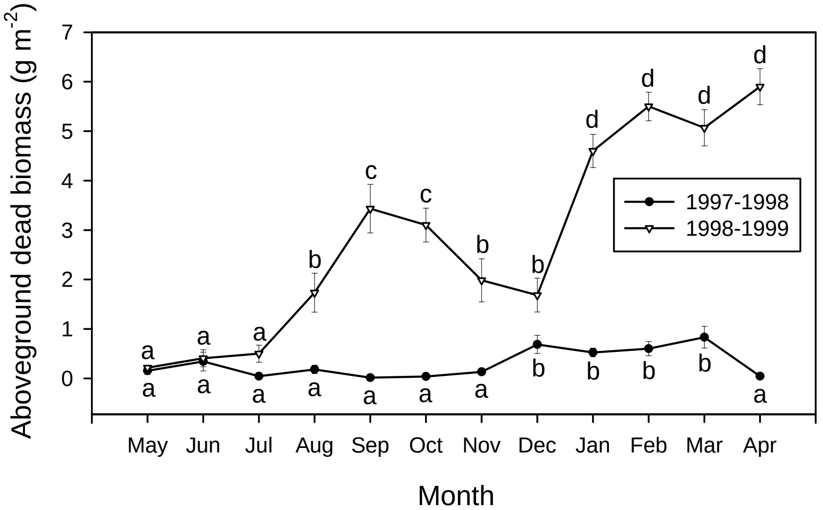

Fig. 6. Seasonal variation in aboveground dead biomass (g m^{-2}) of *Cressa cretica*. Different letters for each year represent significant (p<0.05) differences between months (Bonferroni test).

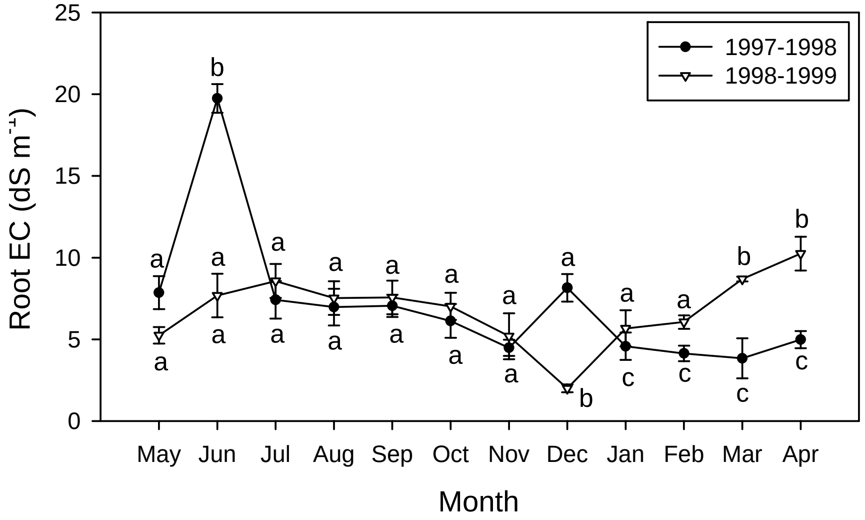

Fig. 7. Electrical conductivity (dS m^{-1}) of belowground of *Cressa cretica*. Different letters for each year represent significant (p<0.05) differences between months (Bonferroni test).

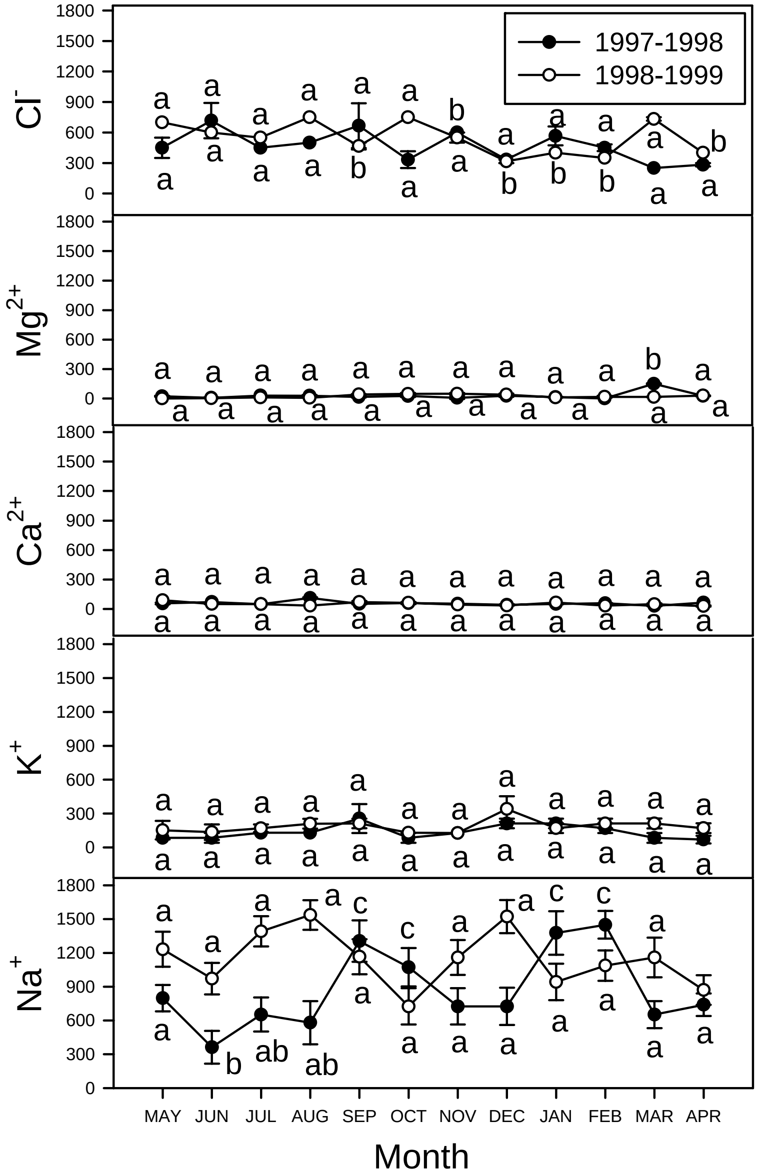

Fig. 8. Ion concentration (µmol g^{-1} dry wt.) in aboveground parts of *Cressa cretica*. Different letters for each year represent significant (p<0.05) differences between months (Bonferroni test).

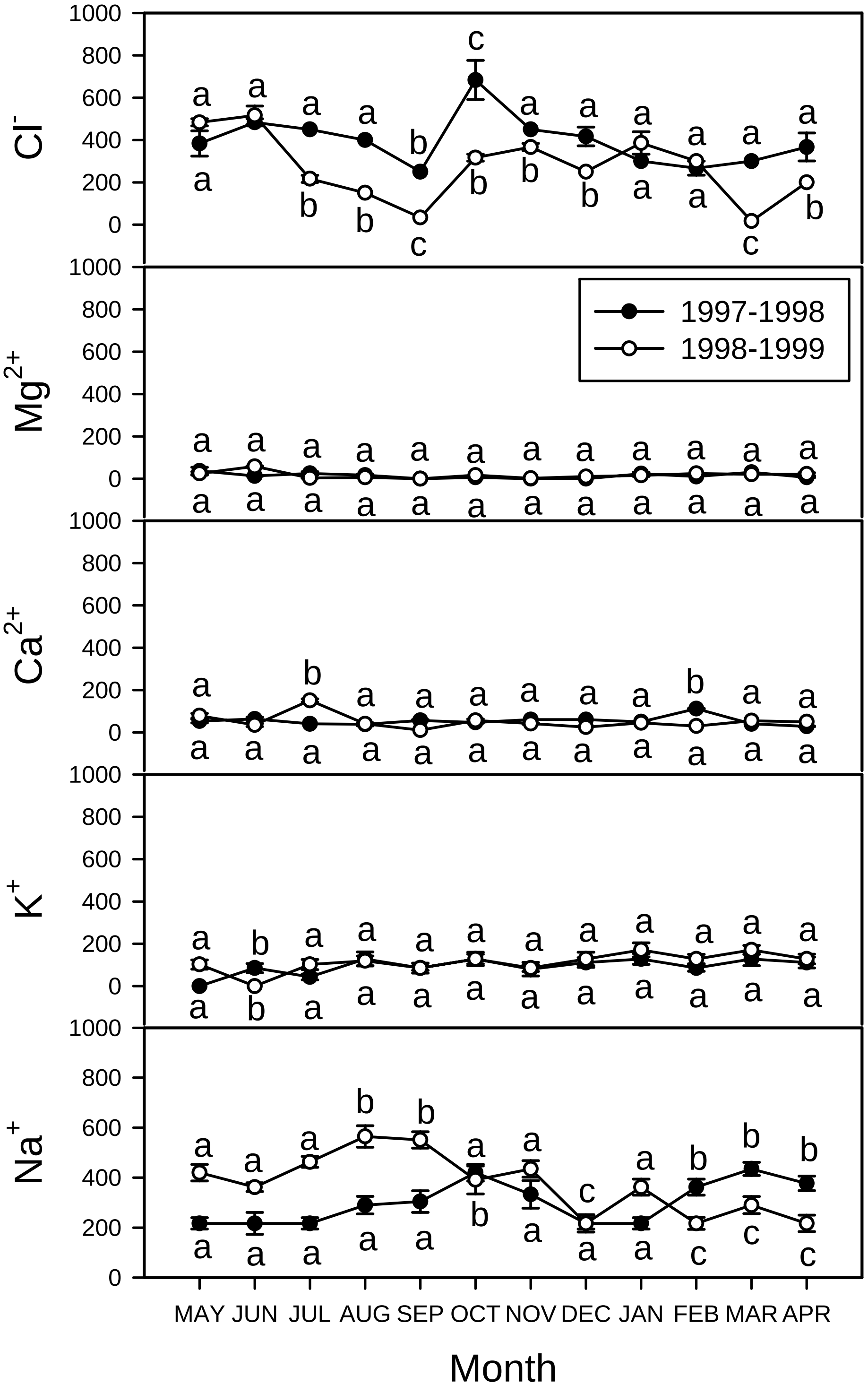

Fig. 9. Ion concentration (µmol g^{-1} dry wt.) in belowground parts of *Cressa cretica*. Different letters for each year represent significant ($p<0.05$) differences between months (Bonferroni test).

Discussion

Productivity of sub-tropical coastal marshes is affected by drought, salinity and temperature (Gul & Khan, 1999). Coastal and estuarine salt marshes are among the worlds most productive natural ecosystems (Howes, *et al*., 1986). Productivity in desert ecosystems is generally limited by moisture availability and is highly variable in space and time (Waide *et al*., 1999; Mittelbach *et al*., 2001). Desert ecosystems are typically on the low end of the productivity gradient ranging between 0 and 600 g m^{-2} yr^{-1}. Some experimental studies with herbaceous plants have shown an increase in net primary productivity with an increase in the diversity of species or functional groups (Waide, *et al.*, 1999; Mittelbach *et al.*, 2001). In grassland and dune sites of Songnem it was observed that *Leymus chinensis* showed a difference in pattern of biomass allocation in two growing years 1997 and 1998 mainly because of precipitation (Ronzhong *et al.*, 2000).

Annual net primary productivity may be reduced by either high or low soil moisture (Santos & Esteves, 2002). These extremes could be due to lack of rainfall in desert coastal areas (Gul & Khan, 1999) or heavy rainfall characteristics of coastal prairies in the US (Santos & Esteves, 2002). In addition to the role of water in productivity nutrients like phosphorus and available oxygen could contribute significantly in increasing productivity (Lorenzen *et al.*, 2001; Hong *et al.*, 2002; Santos & Esteves, 2002).

Cressa cretica dominates the sand dunes near the Arabian Sea coast. The net productivity varied from one season to the other and also within the season. Productivity increased with the emergence of new shoots and progressively increased up to flowering and subsequently the plant dies after seed production. Surface and near surface soil salinity appear to play only a minor role in the productivity of *C. cretica* because it harvests water from deeper layers of dunes. Belowground biomass was lower than the aerial parts and showed little variation between seasons. Good *et al.*, (1982) reported that belowground biomass was either equal to or greater than the aboveground biomass. Belowground biomass of the herbaceous community was about 40% of the total biomass and it could also be affected by grazing, herbivory and predation (Wallace & O'Hop, 1985; Paling & McComb, 2000). Lower belowground biomass recorded could also be due to the sampling method used. Rhizomes and roots attached directly to aerial parts were harvested but the whole matrix of rhizome system was avoided.

Aboveground biomass was highest during August and November of both seasons perhaps due to sporadic rainfall. Growth in both seasons peaked in fall. Shoot productivity was also quite variable based on various environmental factors. The fluctuating hydro-periods are usually prominent in most published discussions of physical factors affecting marsh production (Jurado & Wester, 2001; Santos & Esteves, 2002; Mata-Gonzales *et al.*, 2002; Feldmann & Nöges, 2007). Soil salinity and temperature were higher before the rains which caused substantial reduction in aboveground biomass in the present study as is reported to lower plant production (Zedler *et al.*, 1980). The above ground production of *C. cretica* salt marsh ranged from 200 to 485 g m^{-2} yr^{-1} which is the lower in comparison to *Salicornia* marshes in California (300-1200 g m^{-2} yr^{-1}, Zedler, 1982) and *Batis maritima* and *Salicornia virginica* marshes in Georgia respectively, (1,149 g m^{-2} yr^{-1} and 600 g m^{-2} yr^{-1}, Antlfinger & Dunn, 1979) and from *Salicornia europaea* marshes in Massachussets (234 g m^{-2} yr^{-1}; Rubers & Murray, 1978). Dawes (1981) reported the aboveground estimates of primary production of salt marshes at approximately 300-4000 g m^{-2} yr^{-1}. Aboveground biomass of *Juncus kraussi* in Australia ranged from 96-4400 g m^{-2} yr^{-1}and for *Sporobolus virginicus* from 148-852 g m^{-2} yr^{-1} (Clarke & Jacoby, 1994).

Soil conductivity which was monitored for 2 years showed similar seasonal trends in both years. Highest conductivity reported was around 35-59 dS m^{-1}. This could be due to the little rainfall (90 mm) during the entire season. Plant tissue conductivity ranged from 20-22 dS m^{-1}.

Productivity under natural conditions appears to be controlled by variation in temperature and moisture. Although plants usually survive on underground brackish water but the addition of fresh water substantially increased the productivity under natural conditions. *Cretica cretica* halophytes could be propagated through direct seawater irrigation in coastal areas for dune stabilization and greenification.

References

Antlfinger, A.E. and E.L. Dunn. 1979. Seasonal patterns of CO_2 and water vapor exchange in three salt marsh succulents. *Oecologia.*, 43: 249-260.

Boland, A.M., P.H. Jerie, P.D. Mitchell, J.L. Irvine and N. Nardella. 1996. The effect of saline water table on peach tree water use, growth, productivity and ion uptake. *Aust. J. Agri. Research.*, 47: 121-139.

Clarke, P.J. and C.A. Jacoby. 1994. Biomass and aboveground productivity of salt marsh in South-eastern Australia. *Aust J Marine and Freshwater Research* 45: 1521-1528.

Dawes, C.J. 1981. Marine Botany. John Wiley and Sons. New York.

Feldmann, T. and P. Nöges. 2007. Factors controlling macrophyte distribution in large Lake Vortsjärv. *Aquatic Botany,* 87: 15-21.

Gheyi, H.R. 2000. Problemas de salinidade na agricultura irrigada. In: (Eds.): T. Oliveira, Jr. Asiss, R.N., Romeo, J.R.C. Silva. Agricultura, sustentabilidade e o semi-arido. Sociedade Brasileira de Ciência do Solo, Fortaleza (UFC), 329-345.

Glenn, E.P. and J.J. Brown. 1999. Salt tolerance of potential halophytes. *Critical Reviews in Plant Sci.*, 18: 227-255.

Good, R.E., N.F. Good and B.R. Frasco. 1982. A review of primary production and decomposition dynamics of the belowground marsh component. In: (Ed.): V.S. Kennedy. Estuarine comparisons. Academic Press., New York, pp. 139-157.

Gul, B. and M.A. Khan. 1999. Effect of intraspecific competition and inundation regime on the growth of *Arthrocnemum macrostachyum* in a coastal swamp in Karachi. Pakistan. *Pak. J. Bot.*, 31: 163-172.

Hamdy, A., H. Lieth, Todorovie and M. Moschenko. 1999. Halophyte uses in different climates II. Halophytic crop development: Pilot studies. Progress in Bimeterology Volume 14. The Netherlands: Backhuys Publishers, Leiden.

Hillman, K., D.I. Walker, A.W.D. Larkum and D.A.J. Mc Comb. 1989. Productivity and nutrient limitation. In: (Eds.): A.W.D. Larkum, A.J. McComb and S.A. Shepherd. Biology of sea grasses: a treatise on the biology of sea grasses with special reference to the Australian region 635-685. Elsevier, Amsterdam.

Howes, B.L., J.W.H. Dacey and D.D. Goehringer. 1986. Factors controlling the growth form of *Spartina alterniflora*. Feedbacks between aboveground production, sediment oxidation, nitrogen and salinity. *J. Ecol,* 74: 881-898.

Hong, Z., G. Shangyu and Z. Qiuhong. 2002. Responses of NPP of salinized meadows to global change in hyperarid regions. *J. Arid Environ.*, 50: 489-498.

Irlandi, E., B. Orlands, S. Macia, P. Biber, J. Tahzay, L. Kaufman, D. Lirman and E.T. Patterson. 2001. The influence of freshwater run off on biomass, morphometrics and production of *Thalassia testudinum*. *Aquatic Botany*, 72: 67-78.

Jobbagy, E., O.E. Sala and J.M. Parnelo. 2002. Patterns and controls of primary production in the Patagonian steppe: a remote-sensing approach. *Ecology,* 83: 307-319.

Jurado, P. and D.B. Wester. 2001. Effects of biosolids on tobosa grass growth in the Chihuahua desert. *J. Range Management,* 54: 89-95.

Kenworthy, W.J. and G.W. Thayer. 1984. Production and decomposition of the roots and rhizomes of seagrasses *Zostera marina* and *Thalassia testudinum,* in temperate and subtropical marine ecosystems. *Bulletin of Marine Sciences,* 35: 264-369.

Laclan, J.P., W.S. Poumba, J.D. Nzlia, J.P. Bouillet and J. Ranger. 2002. Biomass nutrient dynamics in a littoral savanne subjected to annual fires in Congo. *Acta Oecologica,* 23: 41-50.

Lagergran, F., L. Eklundh, A. Grelle, M. Lunblad, M. Molder, H. Lankreijer and A. Lindroth. 2005. Net primary production and light use efficiency in a mixed coniferous forest in Sweden. *Plant Cell and Environ.,* 28: 412-423.

Lieth, H. 1972. Modeling the primary productivity of the world. *Tropical Ecology* 13: 125-130.

Lieth, H., M. Moschenko, M. Lohman, H-W. Koyro and A. Hamdy. 1999. Halophyte uses in different climates I. Ecological and ecophysiological studies. Progress in Biometearology Volume 13. The Netherlands Backhuys Publishers, Leiden.

Lorenzen, B., H. Brix, I.A. Mendelssohn, K.L. Mckee and S.L. Miao. 2001. Growth, biomass allocation and use efficiency in *Cladium jamaicense* and *Typha domingensis* as affected by phosphorus and oxygen availability. *Aquatic Botany*, 70: 117-133.

Mata-Gonzalez, R., R.E. Sosebee and C. Wan. 2002. Shoot and root biomass of desert grasses as affected by biosolids application. *J. Arid Environ.*, 50: 477-488.

Mittelbach, G.G., C.F. Steiner, S.M. Scheiner, K.L. Gross, H.L. Reynolds, R.B. Waide, M.R. Willig, S.I. Dodson and L. Gough. 2001. What is the observed relationship between species richness and productivity. *Ecology* 82: 2381-2396.

Munns, R. 2002. Comparative physiology of salt and water stress. *Plant Cell and Environ.,* 25: 239-250.

Paling, E.I. and A.J. McComb. 2000. Autumn biomass, belowground productivity, rhizome growth at bed edge and nitrogen content in sea grass from Western Australia. *Aquatic Botany.,* 67: 207-219.

Ronzhong, W., E.A. Ripley, Z. Yuangang and N. Shaoquan. 2000. Demography of reproductive and biomass allocation of grassland dune *Leymus chinensis* on the Songnen Plain, North-Eastern China. *J. Arid Environ.*, 4: 289-299.

Rubers, E. and R.E. Murray. 1978. Some ideas about coastal management from production and export studies on a Massachusetts salt marsh. Proceedings of New Jersey Mosquito Control Association. 65: 51-58.

Santos, A.M. and F.A. Esteves. 2002. Primary production and mortality of *Eleocharis interstincta,* in response to water level fluctuations. *Aquatic Botany*, 74: 189-199.

Anonymous. 1999. SPSS: SPSS 9.0 for Windows update. Chicago: SPSS Inc.

Thibaut, T., A. Meinesz and P. Coquillard. 2004. Biomass seasonality of Caulerpa taxifolia in the Mediterranean Sea. *Aquatic Botany,* 80: 291-297.

Wallace, J.B. and J.O' Hop. 1985. Life on fast pad: water lily leaf beetle impact on water lilies. *Ecology*, 66: 1534-1544.

Waide, R.B., M.R. Willing, C.F. Steiner, G. Mittelbach, L. Gough, S.I. Dodson, G.P. Juday and R. Parameter. 1999. The relationship between productivity and species richness. *Ann. Rev. Ecol. Sys.,* 30: 257-300.

Yahdjian, L. and O.E. Sala. 2006. Vegetation structure constrains primary production response to water availability in the Patagonian steppe. *Ecology*, 87(4): 952-962.

Zedler, J.B. 1982. The ecology of southern California coastal marshes: a community profile. United States. Fish and Wildlife Service FWS/ OBS-81/54.

Zedler J.B., T.P. Winfield and Williams. 1980. Salt marsh productivity with natural and altered tidal circulation. *Oecologia,* 44: 236-240.

(Received for publication 3 January 2009)