

H G Kutbay and M Demir

The Changes in Contents of Salt Marsh Species and the Importance of Edaphic Physicochemical Factors

Abstract: The changes in nutrient contents of some halophytic plants which occurred in a salt marsh located in the vicinity of Bafra town, on the north coast of Turkey during the growing season were investigated. Contents of SO_4 , Cl, Na, K, Ca and Mg changed during the growing season in most species. High correlation coefficients were obtained between plant ion and soil ion contents. It has been found that the most prevalent ion was Na in the plant and soil samples. It was also shown that species diversity was quite low in the study area, and species diversity was highly correlated with SO_4/Cl ratio, electrical conductivity and pH.

Key words: Salt marshes, Ion contents, Ion ratios, Species diversity.

Introduction

Coastal salt marshes comprise areas of land bordering seas and lakes and are subjected to periodic inundation by tides (Krüger and Peinemann, 1996; Asri and Ghorbanli, 1997). Such ecosystems are generally dominated by a small number of halophytic species that are spatially segregated in pronounced vegetation zones (Bertness *et al.*, 1992).

The success of salt marsh plants have been affected by nutrient limitations and salinity (Pennings and Callaway, 1992). Halophytes have developed a number of mechanisms to avoid and resist salt stress, such as salt hairs and salt glands, succulence, dilution of salts by increased growth, osmotic adjustment, compatible osmotica, root excretion of salts, and selective ion uptake by roots (Ungar, 1998).

Hamdi G Kutbay and Mustafa Demir
University of Ondokuz Mayıs
Faculty of Arts and Sciences,
Department of Biology, 55139
Kurupelit-Samsun, Turkey
E-mail:hquray@omu.edu.tr

التغيرات في محتوى السبخات المالحة من النباتات وأهمية صفات التربة من الناحية الفسيولوجية الكيميائية

حمدي كتبي و مصطفى دمير

المستخلص: لقد تمت دراسة المحتويات الغذائية لبعض النباتات الملحية التي تتواجد في السبخة الواقعة بالقرب من مدينة بفرّا على الساحل الشمالي لتركيا وقد وجد أن المحتويات من الكبريتات (SO_4)، الكلور (Cl)، الصوديوم (Na) البوتاسيوم (K) الكالسيوم (Ca) والمغنيسيوم (Mg) قد تغيرت جميعها في فصل النمو. وقد وجد أن هناك علاقة إحصائية ذات قيمة معنوية عالية بين العناصر النباتية وما تحتوية التربة التي تنمو فيها النباتات من معادن. وقد وجد أن أكثر العناصر شيوعاً هو الصوديوم (Na) وقد لوحظ بأن التنوع النباتي في منطقة الدراسة كان قليلاً جداً، ولكنه كان عالياً في المناطق التي يتواجد فيها الكبريتات والكلور (SO_4/Cl) وذلك نتيجة التوصيل الكهربائي والأس الهيدروجيني (PH).

كلمات مدخلية: سبخة، محتوى العناصر، نسبة العناصر، مقدار التنوع النباتي

Physiochemical factors, such as salinity and flooding, are often considered to be the determining factors controlling the establishment and zonation patterns of species in salt marshes (Ungar, 1998). Biotic factors, such as interspecific competition, symbiont activity and pressure by herbivores and parasites, may play additional important roles in shaping salt-marsh vegetation (García *et al.*, 1993).

In this study the changes in ionic contents of some halophytic plants during the growing season were investigated in a salt marsh situated in Samsun on the north coast of Turkey. The interaction between plant and soil ionic contents was also investigated and the differences in respect to plant and soil ionic contents are discussed. The other aim of this study is to investigate the effects of plant and soil factors on species diversity.

Study Area

The study area is one of the main routes for bird migration, therefore this area has a particular ecological interest and as such was declared a protected area mainly for the purpose of preparing a management plan in order to secure proper

conservation (Yarar and Magnin, 1997). The area is situated in the Central Black Sea Region, in the north of Turkey and located at Kosu village 20 km from Bafra town and 1 km east from the mouth of the Kizilirmak river (Figure 1). A canal lies on the edge of the area. Two different zones are present in the area. The first zone is near the canal and characterized by *Salicornia prostrata* Pall. and *Spergularia marina* (L.) Gris. The second zone is slightly higher than the first one and dominated by *Artemisia santonicum* L., *Aster tripolium* L. and *Suaeda prostrata* Pall. subsp. *prostrata*. Some other species in the area are *Trifolium campestre* Schreb., *Pulicaria dysenterica* (L.) Cass., *Filago eriocephala* Guss., *Blackstonia perfoliata* (L.) Hudson subsp. *perfoliata*, *Centaurium pulchellum* (Swartz) Druce, *Anagallis arvensis* L. var. *arvensis*. Taxonomic nomenclature followed that of Davis (1965-1988).

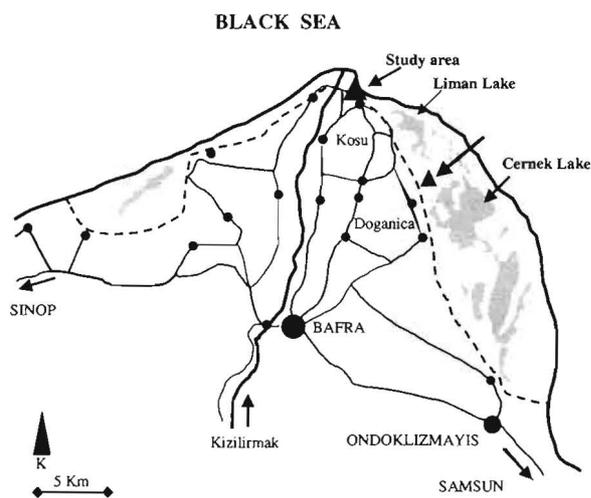


Fig.1: Map of the location area

Materials and Methods

Leaf samples of the halophytic species (eighteen subsamples in a 16 m² area) were taken during the growing season from September 1997 to June 1998. Plant samples were dried at 70°C and sieved. Sieved plant samples were grounded in a Wiley mill to 425 µm (40 mesh) and digested in a mixture of nitric and perchloric acids. Na, K, Ca and Mg (%) contents were determined by using a Perkin Elmer 2280 atomic absorption spectrophotometer. SO₄ (%) was determined using a turbidimetric method. Cl (%) was estimated by titration against AgNO₃ after dry combustion of plant samples at 550°C for 5-6 hours (Marr and Cresser, 1983; Allen *et al.* 1986).

Soil samples were taken using a 7 cm. diameter auger to a depth of 50 cm. These samples were air-

dried, crushed and sieved using a 2 mm mesh. About 150 g of soil sample was dried in an oven at 80°C until constant weight. A 100 g subsample was then used for the mechanical analysis. Soil texture was determined by mechanical sieving. Electrical conductivity and pH were determined in soil: water extracts at 1:1 (w:v) using a Jenway analyser. Water soluble Na, K, Ca and Mg (meq/l) were determined using a Perkin Elmer atomic absorption spectrophotometer. SO₄ and Cl (meq/l) were determined by turbidimetric and gravimetric methods, respectively (Black, 1965; Marr and Cresser, 1983; Allen *et al.*, 1986).

Species diversity was calculated as the Shannon-Wiener index $H' = -\sum_{i=1}^S P_i \log_2 P_i$ where S is the total number of species and P_i is the relative cover of i th species (Pielou, 1975; Russell *et al.*, 1985; El-Demerdash, 1996).

The differences in ionic content of plants during the growing season were assessed using a one-way ANOVA test. Pearson correlation coefficients were also calculated. Statistical analyses were performed using the MINITAB software package (Schaefer and Anderson, 1989).

Results

The soils in the area are predominantly silty-clay, calcareous and saline.

The highest SO₄ (%) content for *Spergularia marina* was observed in September. However the highest values for *Salicornia prostrata* and *Suaeda prostrata* subsp. *prostrata* were observed in June and the highest values for *Artemisia santonicum*, *Aster tripolium* were observed in March. The lowest values were observed in December (Figure 2).

There were significant differences in SO₄ values in *S. marina*, *S. prostrata*, *A. santonicum* and *S. prostrata* subsp. *prostrata*. However, there were no significant differences in SO₄ values in *A. tripolium* (Table 1).

S. marina, *S. prostrata*, *S. prostrata* subsp. *prostrata* and *A. tripolium* had the highest Cl (%) content in September. However, the highest Cl (%) content for *A. santonicum* was found in June. As observed for *A. tripolium*, the lowest Cl (%) content for this species was also observed in December (Figure 2).

Cl (%) contents differed significantly in all species (Table 1).

The highest Na (%) content in *S. marina*, *S. prostrata*, *S. prostrata* subsp. *prostrata* and *A. santonicum* were observed in September, while the lowest Na (%) content was observed in December, except for *S. marina* and *S. prostrata*. The lowest values for these latter species were observed in March (Figure 2).

For all species except *S. marina*, there were significant differences during the growing season in Na (%) values (Table 1).

The highest K(%) content for *S. marina*, *S. prostrata*, *S. prostrata* subsp. *prostrata*, *A. tripolium* and *A. santonicum* were obtained in March, while the lowest values were found in September and December (Figure 2).

Statistically significant differences were observed in terms of K(%) contents in all species, except *S. marina* (Table 1).

S. marina and *A. tripolium* had the highest Ca (%) contents in December and March respectively. The lowest values were observed in June. *S. prostrata*, *S. prostrata* subsp. *prostrata* and *A. santonicum* had the highest and lowest Ca (%) contents in September and December, respectively (Figure 2).

No significant differences were observed in the Ca (%) content of *A. tripolium* during the growing season. However, significant differences were observed for the other species (Table 1).

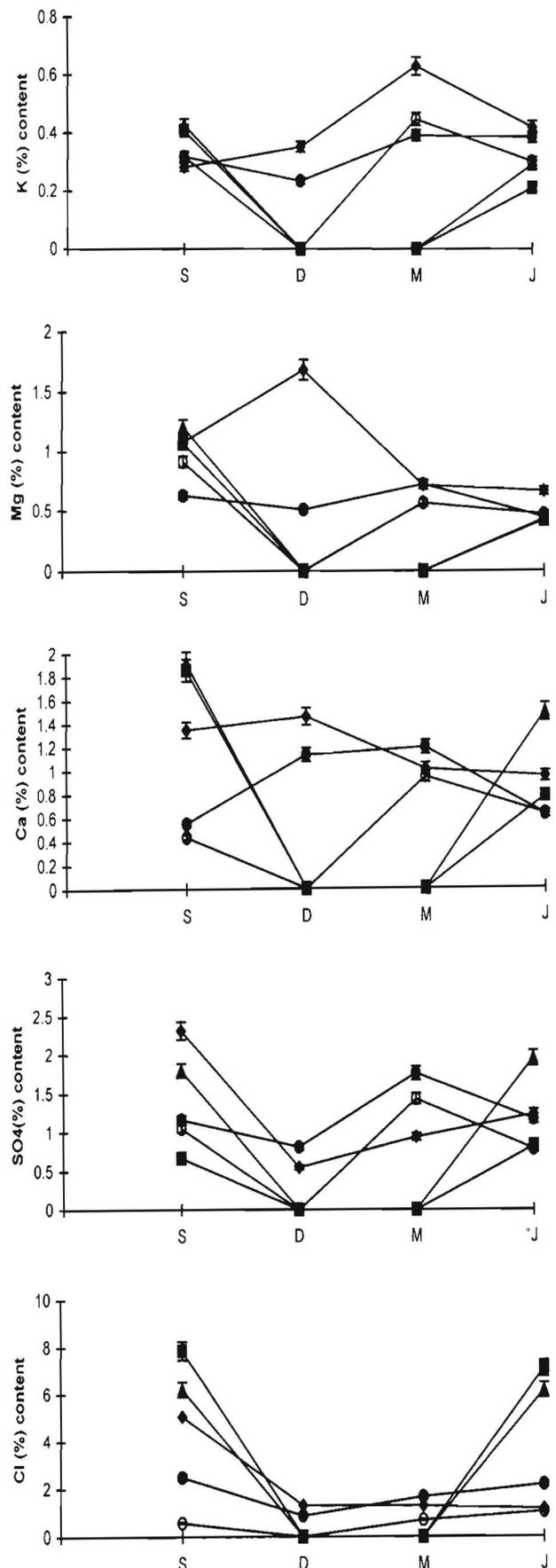
Highest Mg (%) values were observed for *S. marina* and *A. tripolium* in December and March, respectively. However, the lowest values were observed in June and September, respectively. Highest and lowest values for the other species were observed in September and December, respectively (Figure 2).

Mg (%) values changed significantly during the growing season, except in *S. marina* (Table 1).

Mean values of soil parameters and the changes in soil parameters during the growing season are shown in Table 4 and Figure 4, respectively. There were no significant differences between first and second zones with respect to soil parameters except exchangeable Na ($F=5.640$; $P<.05$). pH values changed significantly during the growing season in the first zone ($F=5.278$; $P<.01$). However the other soil parameters were not significantly different in the first and second zones during the growing season.

Species diversity was lower in the first zone as compared to the second zone (Figure 5). Species diversity peaked during October and May in the second zone, and the highest values were obtained

in the first zone during August. A remarkable decrease was observed during November, at the beginning of flooding in both zones.



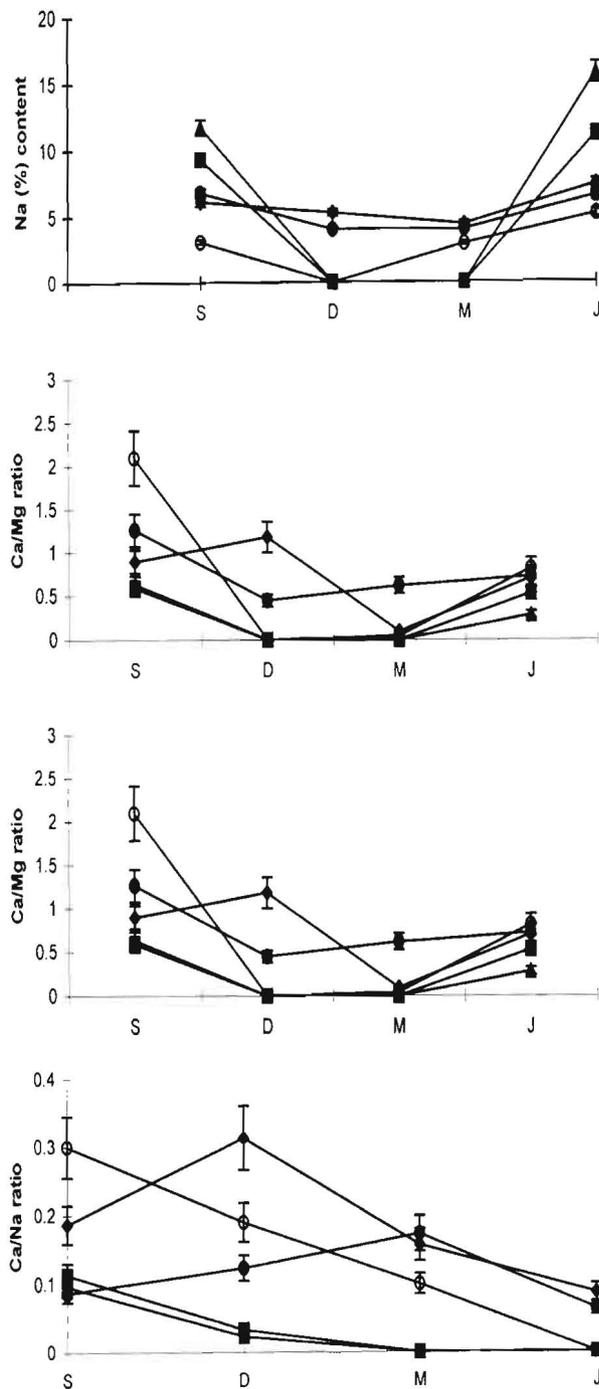


Fig. 2; The changes in ionic contents (%) during the growing season.

S: September, D: December, M: March, J: June
Standard errors are also given)

- ◆ Species
- *Salicornia prostrata*
- ▲ *Suaeda prostrata*
- *Artemisia santonicum*
- *Aster tripolium*

Table 1. Significant differences in nutrient content during the growing season

Species	Ion (meq/l)	F-Value	Sig.
<i>S. marina</i>	SO ₄	13.460	*
<i>S. prostrata</i>	SO ₄	6.381	*
<i>S. prostrata</i> subsp. <i>prostrata</i>	SO ₄	225.570	**
<i>A. santonicum</i>	SO ₄	20.070	*
<i>S. marina</i>	Cl	18.022	*
<i>S. prostrata</i>	Cl	790.590	**
<i>S. prostrata</i> subsp. <i>prostrata</i>	Cl	218.020	**
<i>A. santonicum</i>	Cl	53.730	**
<i>A. tripolium</i>	Cl	39.360	**
<i>S. prostrata</i>	Na	22.390	*
<i>S. prostrata</i> subsp. <i>prostrata</i>	Na	735.680	**
<i>A. santonicum</i>	Na	8.850	*
<i>A. tripolium</i>	Na	10.240	*
<i>S. prostrata</i>	K	10.901	*
<i>S. prostrata</i> subsp. <i>prostrata</i>	K	450.770	**
<i>A. santonicum</i>	K	658.690	**
<i>A. tripolium</i>	K	42.555	**
<i>S. marina</i>	Ca	11.480	*
<i>S. prostrata</i>	Ca	60.210	**
<i>S. prostrata</i> subsp. <i>prostrata</i>	Ca	310.510	**
<i>A. santonicum</i>	Ca	80.050	**
<i>S. prostrata</i>	Mg	70.990	**
<i>S. prostrata</i> subsp. <i>prostrata</i>	Mg	214.600	**
<i>A. santonicum</i>	Mg	632.190	**
<i>A. tripolium</i>	Mg	21.500	*

Sig. = Significance * P<0.05 **P<0.01

Discussion

Yeo (1983) concluded that halophytic plants may accumulate Na and Cl to provide osmotic adjustment and the turgor to maintain growth. According to Krüger and Peinemann (1996) halophytic species accumulated some cations, especially Na, in their leaves. In the present study the Na content of the leaves of the species was higher than the other cations (Figure 2).

Waisel (1972) stated that synergistic and antagonistic relationships between cations have an important effect on ion uptake. Flowers *et al.* (1977) and Jenny *et al.* (1990) noted that high Na contents have an inhibitory effect on K. In the present study K contents of halophytic plants extended from 0.11-0.933 % (*S. marina*), however Na contents reached 16.683 % (*S. prostrata* subsp. *prostrata*) (Figure 2). Similarly Ca and Mg contents were lower than Na contents. Additionally Ca/Na ratios became closer from March to June (Figure 3) and plants may be affected by the Na surplus. In addition to this

dominating Na content, in relation to the Ca and Mg, may effect a salt induced nutrient deficiency and close Ca/Na ratios may also cause an unequal supply of nutrients (Jenny *et al.*, 1990). High Na/K ratios show that there was an inhibitory effect between Na and K. In the present study Na/K ratios extended from 6.602 to 30.055 % (Figure 3).

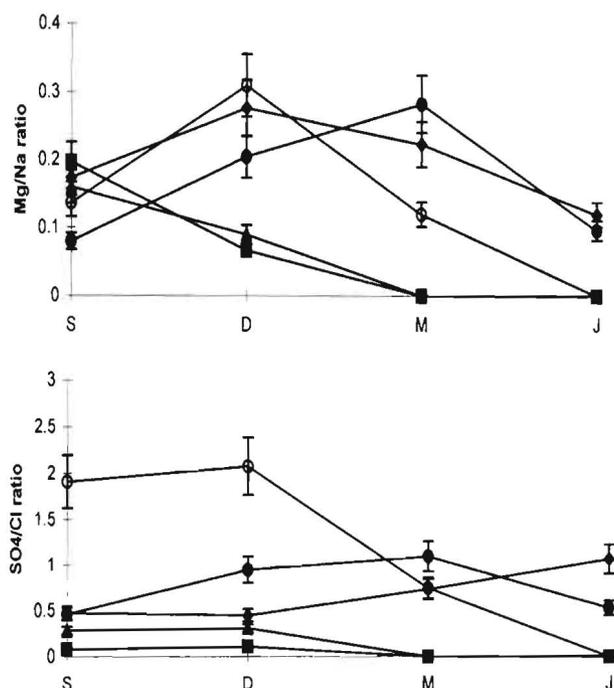


Fig. 3: Ion ratios during the growing season
S: September, D: December, M: March, J: June
Standard errors are also given)

- ◆ Species
- *Salicornia prostrata*
- ▲ *Suaeda prostrata*
- *Artemisia santonicum*
- *Aster tripolium*

Cl contents in the present study were quite similar to the values reported by Kruger and Peinemann (1996). Howard and Teal (1980) explained that SO₄ has an important role in sulphur cycles in salt marshes. High correlation coefficients were obtained between SO₄ and Cl for most species (Table 2). Such a close relationship between chloride and sulphate were also reported by Van der Molen (1976).

Table 2. Correlation coefficients between SO₄ and Cl (n=18).

Species	r	Sig.
<i>S. marina</i>	0.914	**
<i>S. prostrata</i>	0.977	**
<i>S. prostrata</i> subsp. <i>prostrata</i>	0.998	**
<i>A. santonicum</i>	0.707	**
<i>A. tripolium</i>	0.134	NS

Sig. = Significance ** P<0.01 NS: Not significant.

There was a negative correlation between plant Ca and Na (r=-0.549;P<0.05). Jenny *et al.* (1990) argued that there was an antagonistic effect between plant Ca and Na

Ion abundance of different species is shown in Table 3. *S. marina*, *S. prostrata*, *S. prostrata* subsp. *prostrata* usually had a higher ion content than *A. santonicum* and *A. tripolium*. These results indicated that succulent halophytes have a higher cation content than non-succulent plants and this agreed with the results of Wiebe and Walter (1972) and Krüger and Peinemann (1996). The prevalent ions in all species studied was Na and Cl. The other ions were ranked in the order of SO₄ > Ca=Mg>K.

Table 3. The quantitative abundance of ions in halophytic plants.

Ion	The order of ions
Na	Sua. > Sal. > Ast. > Art > Sperg.
K	Sal > Sua. > Art > Ast. > Sperg.
SO ₄	Sperg.> Sua. > Ast. > Sal. > Art.
Cl	Sal. > Sua. > Sperg.> Ast. > Art.
Ca	Sperg.> Sal. > Sua. > Ast. > Art.
Mg	Sua. > Sal. > Sperg > Art. > Ast.

Sperg.: *Spergularia marina* Sal.: *Salicornia prostrata*
Sua.:*Suaeda prostrata* subsp. *prostrata*
Art.: *Artemisia santonicum* Ast.: *Aster tripolium*.

Halophytic plants are defined as hyperhalophytes, with a very high salt content. Euhalophytes, which are characterized with having a high salt tolerance and growing in very saline soils, predominate in communities with less salinity in the substratum, hemihalophytes, (which are the plants of moderately saline soils), and haloglycophytes due to their adaptability to sandy soils (Akjigitova, 1995). In the present study the halophytic species may be classified as hyperhalophytes according to the classification of Akjigitova (1995). Ellenberg *et al.* (1992) classified halophytic plants according to the chloride contents in the root zone by using a 1-9 scale, from glycophytes to hyperhaline halophytes. Halophytic species in the study area may be classified as euhaline to hyperhaline according to the chloride contents in the root zone. However, such classification systems were not sufficient for all halophytic species. For example, the prevailing ion type in saline soils is too important to the classification of halophytes, so that Ellenberg's classification (1992) was not useable for all halophytes, because only chloride contents were examined in Ellenberg's classification system.

Cl and Mg contents of all species in the study area changed during the growing season. SO₄, Na, K and Ca contents also changed in most species (Table 1). Flooding is considered to be the determining factor controlling the establishment and zonal patterns of species in salt marshes (Vince and Snow, 1984; García *et al.*, 1993). Flooding was observed in the first and second zones and it began at the end of November and finished in the first half of May. It continued for about 170 days. There were statistically significant differences between the first and second zones in terms of above ground water levels ($F=5.206$; $P<.05$). Thus, one of the main causes of the changes in ionic contents were seasonal inundation and hence waterlogging.

Woodell (1985) and Keiffer and Ungar (1997) classified halophytic species on the basis of species location along a salinity gradient. It has been reported that *Salicornia* L. species are subjected to frequent, long-lasting periods of inundation and they are classified as Type 3, based on Woodell's classification (Keiffer and Ungar, 1997). Keiffer and Ungar (1997) have also pointed out that *S. marina* could be classified as Type 2, because this species occurs in the areas that are occasionally inundated. However, in the study area *S. marina* usually occurs in the first zone with *Salicornia* and it may be classified as a transitional species between Type 2 and 3. *S. prostrata* subsp. *prostrata* and *A. tripolium* may also be classified as a transitional species. *A. santonicum* may be classified as Type 2 based on Woodell's classification.

S. prostrata and *S. marina* were usually located in the first zone and rarely occurred in the second zone. The other three species were usually located in the second zone. Upper salt marsh species could not become established in the lower salt marsh because of their low salt tolerance. As shown in Table 4, soil samples belonging to the first zone have high values in terms of the main parameters of salinity, such as Na, Cl, EC, exchangeable Na and water table, although there were no statistically significant differences between the two localities except for exchangeable Na. Flooding was more prevalent and salinities were higher in the low parts of salt marshes than in higher parts as indicated by Ungar (1998).

Low specific richness was recorded in this study, as compared to Garcia's study (1993) and this is also observed by El-Demerdash (1996). Extreme conditions, notably high salinity, act as a filter: species lacking the genotype able to adapt will be excluded from such harsh environments, as pointed

out by Pennings and Callaway (1992) and El-Demerdash (1996). This also indicated that the main indicators of salinity, such as electrical conductivity, pH and plant cation content, are of prime importance for the regulation of species diversity. Species diversity decreased from November to May, probably due to flooding and anoxic conditions (Bertness, 1991). Low species diversity values in the first zone, as compared to the second zone, were attributed to the high salinity values in the first zone (Figure 5).

Table 4. Mean values of soil properties (Standard errors are given in parenthesis).

Locality	Soil Parameter	Mean Values
First zone	SO ₄	1.39 (0.20)
First zone	Cl	57.23 (30.41)
First zone	Na	88.62 (30.30)
First zone	K	1.16 (0.29)
First zone	Ca	1.70 (0.37)
First zone	Mg	6.22 (2.20)
First zone	EC	14.12 (1.96)
First zone	pH	7.63 (9.5x10 ⁻²)
First zone	CEC	15.90 (7.62)
First zone	Exchangeable Na	38.93 (4.35)
First zone	Water Table	72.08 (4.82)
First zone	AGWL**** (cm)	15.33 (2.52)
Second zone	SO ₄	2.21 (0.50)
Second zone	Cl	27.07 (4.43)
Second zone	Na	65.50 (36.58)
Second zone	K	0.66 (0.26)
Second zone	Ca	1.11 (0.17)
Second zone	Mg	2.65 (1.20)
Second zone	EC	8.88 (2.14)
Second zone	pH	7.85 (8.48x10 ⁻²)
Second zone	CEC	10.67 (0.45)
Second zone	Exchangeable Na	24.48 (0.45)
Second zone	Water Table	55.41 (3.28)
Second zone	AGWL**** (cm)	8.44 (1.65)

* Standard error **Electrical conductivity ***Cation exchange capacity ****Above ground water level

There were significant correlations between the Shannon diversity index and SO₄/Cl ratio, electrical conductivity and pH. Electrical conductivity was negatively correlated with the Shannon diversity index; however SO₄/Cl ratio and pH were positively correlated (Table 6). El-Demerdash (1996) has found that soil salinity was negatively correlated with species richness. García *et al.* (1993) have also been found a significant correlation between the Shannon diversity index and electrical conductivity. Based upon our results, species richness depends on species tolerance to toxic conditions as reported by Pennings and Callaway (1992) and García *et al.* (1993).

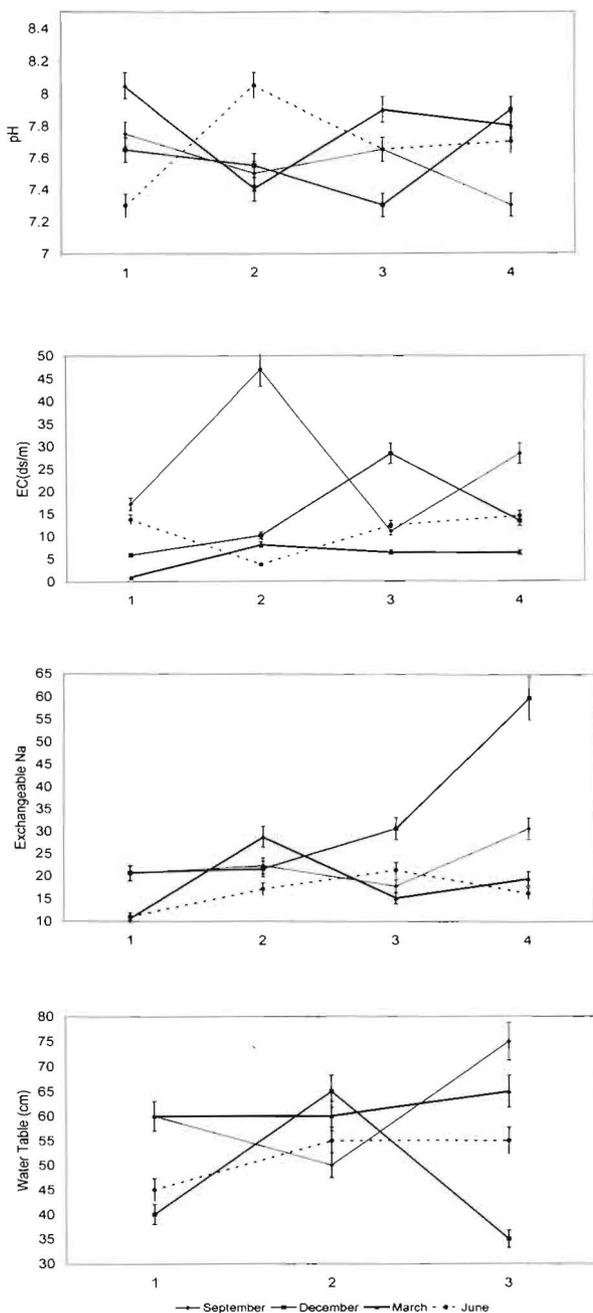


Fig. 4: The changes of soil parameters during the growing season in the second zone

Exchangeable Na percentages in the study area were usually high (Black, 1968). These high exchangeable Na percentages would inhibit the establishment of intolerant species in salt marsh communities by high Na contents or nutrient deficiencies, caused by the replacement in clays of essential macronutrient cations such as Ca and Mg by Na, as pointed out by Ungar (1998). As previously stated, Ca and Mg contents of the species were lower than the Na content.

High correlation coefficients were obtained between plant and soil ion contents in most species,

although such a relationship was not seen in some species (Table 5). These results indicate that soil ionic content appears to determine the spatial patterns of vegetation in most cases, as pointed out by Pennings and Callaway (1992). Additionally, ion specific affects of salinization influence the vegetation pattern. Based upon the results of the present study there were competitive effects between different ions, especially Na and the other ions, and high Na contents in the soil would inhibit the establishment of intolerant species in salt marsh communities.

Table 5. Significant correlation coefficients between plant and soil ionic content (n=18).

Species	Ion	r	Significance
<i>S. marina</i>	SO ₄	0.690	**
<i>A. tripolium</i>	SO ₄	-0.571	**
<i>S. marina</i>	Cl	-0.678	**
<i>A. santonicum</i>	Na	0.732	**
<i>A. santonicum</i>	K	-0.828	**
<i>S. marina</i>	Ca	-0.440	*
<i>A. santonicum</i>	Ca	0.789	**
<i>S. marina</i>	Mg	-0.809	**
<i>A. tripolium</i>	Mg	0.995	**

* P<0.05 ** P<0.01

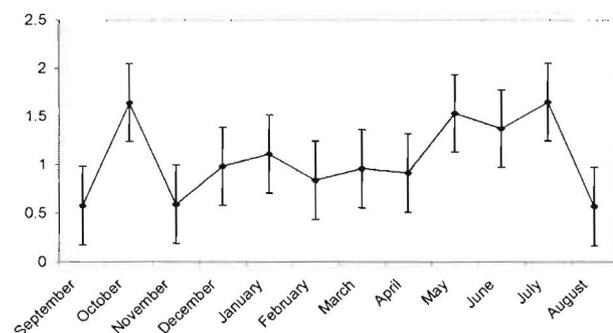


Fig. 5: The changes in species diversity during the growing season

Table 6. Significant correlation coefficients between Shannon diversity index and plant and soil parameters (n=18).

Parameter	r	Significance
SO ₄ /Cl	0.551	*
EC	-0.584	**
PH	0.510	*

*P<0.05 **P<0.01

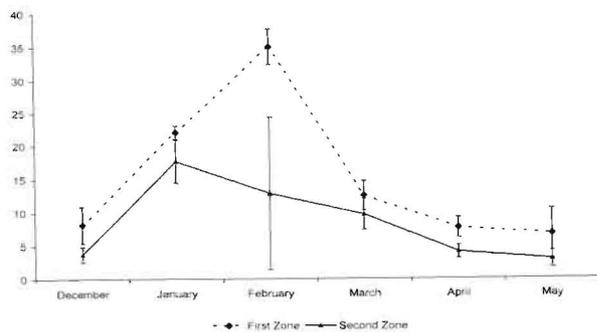


Fig. 6: Above ground water levels (cm) during the growing season

Conclusions

The most prevalent cation and anion in plant and soil samples was Na and Cl, respectively. This corresponds with the results of Jenny *et al.* (1990); Abbas *et al.* (1991) and Krüger and Peinemann (1996). Na and Cl provide osmotic adjustment and turgor to maintain growth for halophytic plants (Yeo 1983). High Na content in relation to the Ca and Mg, may effect a salt induced nutrient deficiency in halophytic plants.

Cation and anion contents significantly changed during the growing season mainly due to seasonal inundation which continued for about 170 days in the study area. The classification of halophytic plants according to the ion content in the root zone were not useable for all halophytes. The clasification of Woodell's (1985) and Keiffer and Ungar's (1997) on the basis of species location along a salinity gradient and inundation period is much more useable for halophytic plants. Specific richness was low in the present study due to extreme habitat conditions. Shannon diversity index was significantly correlated with SO₄/Cl ratio, electrical conductivity and pH. It can be stated that these parameters are of prime importance for the regulation of species diversity. There were competitive effects between Na and the other ions and high Na contents in the soil would inhibit the establishment of intolerant species in salt marsh communities.

Acknowledgements

We would like to express our gratitude to the Research Fund of the University of Ondokuz Mayıs for financial support. We also thank anonymous reviewers for their comments on the manuscript.

References

- Abbas, J. A., Mohammed, S.A. and Saleh M. A. (1991) Edaphic factors and plant species distribution in a protected area in the desert of Bahrain Island, *Vegetatio* **95**:87-93.
- Akjigitova, N. I. (1995) Halophyllous vegetation of Middle Asia. In: Öztürk, M. A., Seçmen, Ö. and Görk, G. (eds.). *Plant Life In Southwest and Central Asia Symposium*, Ege University Press, Izmir, pp. 544-550.
- Allen, S. E., Grimshaw, H. M., Parkinson, J. A., Quarmby, C. and Roberts J. D.(1986) Chemical Analysis. In: Chapman, S.B. (ed) *Methods in Plant Ecology*. Blackwell Scientific Publications, Oxford. pp. 411-466.
- Asri, Y. and Ghorbanli, M. (1997) The halophilous vegetation of the Orumieh Lake salt marshes, N.W. Iran. *Vegetatio* **132**: 155-170.
- Bertness, M. D. (1991) Interspecific interactions among high marsh perennials in a New England salt marsh *Ecology* **72**: 125-137.
- Bertness, M. D., Gough, L. and Shumway S. W. (1992) Salt tolerances and distribution of fugitive salt marsh plants, *Ecology* **73**:1842-1851.
- Black, C. A. (1968) *Soil-Plant Relationships*, John Wiley and Sons Ltd., New York..
- Davis, P. H. (1965-1988) *Flora of Turkey and the East Aegean Islands*, Vol I-X. Edinburgh University Press, Edinburgh.
- El-Demerdash, M. A. (1996) The vegetation of the Farasan Islands, Red Sea, Saudi Arabia, *J. of Vegetation Science* **7**: 81-88.
- Ellenberg, H., Weber, H. E., Düll, R., Wirth, V., Werner, W. and Paulißen, D. (1992) Zeigerwerte von pflanzen in mitteleuropa, *Scripta Geobotanica*, Vol. XVIII, Erich Goltze, Göttingen.
- Flowers, T. J., Troke, P. F. and Yeo A. R. (1977) The mechanism of salt tolerance in halophytes. *Annual Review of Plant Physiology* **28**: 89-121.
- García, L. V., Marañón, T., Moreno, A. and Clemente L. (1993) Above ground biomass and species richness in a Mediterranean salt marsh. *J. of Vegetation Science* **4**: 417-424.
- Howard, R. W. and Teal J. M. (1980) Energy flow in a salt marsh ecosystem: The role of reduced inorganic sulphur compound. *The American Naturalist* **116**: 862-872.
- Jenny, M., Smettan, U. and Facklam-Moniak M. (1990) Soil-vegetation relationship at several arid microsities in the Wadi Araba (Jordan). *Vegetatio* **89**:149-164.
- Keiffer, C. H. and Ungar I. A. (1997) The effect of extended exposure to hypersaline conditions on the germination of five inland halophyte species. *American J. of Botany* **84**: 104-111.
- Krüger, H.R. and Peinemann N. (1996) Coastal plain halophytes and their relation to soil ionic composition. *Vegetatio* **122**: 143-150.

- Marr, I. and Cresser M.** (1983) Environmental Chemical Analysis, International Textbook Company, New York..
- Odum, E. P.** (1974) Halophytes, energetics and ecosystems. *In: Reimold, R. J. and Queen W. H. (eds.) Ecology of Halophytes*, Academic Press, New York..
- Pennings, S. C. and Callaway R. M.** (1992) Salt marsh plant zonation: The relative importance of competition and physical factors, *Ecology* **73**: 681-690.
- Pielou, E. C. and Rowledge R. D.** (1976) Salt marsh vegetation: Latitudinal gradients in the zonation patterns. *Oecologia* **24**: 311-321.
- Russell, P. J., Flowers, T. J. and Hutchings M. J.** (1985) Comparison of niche breadths and overlaps of halophytes on salt marshes of differing diversity. *Vegetatio* **61**: 171-178.
- Schaefer, R. L. and Anderson R. B.** (1989) *The student edition of MINITAB, User's Manual*. Addison Wesley Publishing Company Inc., New York..
- Ungar, I. A.** (1998) Are biotic factors significant in influencing the distribution of halophytes in saline habitats? *The Botanical Review* **64** : 176-199.
- Van den Molen, W.** (1976) Factors to be considered for prognosis, *FAO Soil Bulletin* **31**:31-52.
- Vince, S. W. and Snow A. A.** (1984) Plant zonation in an Alaskan salt marsh 1. Distribution, abundance and environmental factors. *J. of Ecology* **72**:651-667.
- Waisel, Y.** (1972) *Biology of Halophytes*. Academic Press, New York.
- Wiebe, H. H. and Walter H.** (1972) Mineral ion composition of halophytic species from Northern Utah. *The American Midland Naturalist* **87**:241-244.
- Woodell, S. R. J.** (1985) Salinity and seed germination patterns in coastal plants. *Vegetatio* **61**: 223-230.
- Yarar, M. and Magnin G.** (1997) *Turkiye' nin Onemli Kus Alanlari*. Dogal Hayati Koruma Dernegi Yayinlari. Istanbul.
- Yeo, A. R.** (1983) Salinity resistance: Physiologies and prices. *Physiologia Plantarum* **58**: 214-22.

(Received 04/9/2000, in revised form 29/01/2001)