Zora Dajić, Mirjana Stajković & Miodrag Jakovljević

An ecophysiological study of *Suaeda maritima (Chenopodiaceae)* in Serbia

Abstract

Dajić, Z., Stajković, M. & Jakovljević, M.: An ecophysiological study of *Suaeda maritima (Chenopodiaceae)* in Serbia. – Bocconea 5: 511-516. 1997. – ISSN 1120-4060.

The cosmopolitan halophyte, *Suaeda maritima,* has been studied with respect to the physico-chemical properties (anion and cation concentrations, electric conductivity, osmotic potential) of its cell sap, during one vegetation period (July to October 1992), in its native saline habitat near Melenci (Vojvodina, Serbia). The same parameters were measured, in parallel, for the soil as well. *S. maritima* is characterized by low osmotic potential values (–2.59 MPα to –3.25 MPα), for which the importance of ion participation follows the pattern: Na > Cl > SO_4 > K. Sugar content ranged from 17.3 mmol/l to 106 mmol/l. The root/shoot weight ratio gradually increased during the vegetation period, reflecting growing water stress due to ion accumulation in the tissues.

Introduction

Salt resistance of plants is of special theoretical and practical significance in stress physiology, especially when studied under the conditions prevailing in their natural habitats, where soil salinity is paramount among physical, chemical and other ecological factors. Species of *Suaeda* Forssk. ex J. F. Gmel., particularly *S. maritima* (L.) Dumort., are widespread in Europe and world-wide in coastal and continental saline habitats. *Suaeda maritima* has been the subject of several studies devoted to the biology of halophytes (Weisel 1972, Munns & al. 1983, etc.).

With the aim of investigating the influence of salt content variations on plants in their natural habitats, the water regime and chemical contents of the cell sap of *Suaeda maritima* have been examined during one vegetation period, from July to October 1992, at its locality near Melenci (Central Banat, Vojvodina, Serbia). Morphometric measurements of vegetative organs in the flowering phase have been made, in parallel, on a large sample of individuals. Special care was devoted to the analysis of soil ion contents and of the contribution of different ions to the osmotic potential of the plants.

Osmotic adjustment, whereby the salts are used as osmotic solutes causing a decrease of osmotic potential and turgor maintenance, is one of the most important adaptive mechanisms of halophytes to conditions of high soil salinity (McKree 1986). A very important feature of osmotic adjustment is the supply of ions from the root to the leaves of succulent halophytes, such as *Suaeda maritima*, which is why significant amounts of sodium, potassium and chlorine ions occur in the vacuoles of mesophyll parenchyma cells (Flowers & Yeo 1986). It is believed that the rapid uptake of Na^+ and Cl^- by halophytes is related to the fact that these ions represent main osmotic solutes in their tissues (Greenway & Munns 1980, Wyn Jones & al. 1979).

Table 1. Seasonal changes of ion concentrations (mmol/l) in the soil at the locality studied, with cation sum (Σcat), anion sum (Σan), electronic conductivity (EC, mS/cm), overall salt quantity (Σsalt, mg/l), and acidity (pH).

	Na^+	K^+	¼Ca^{2+}	½Mg^{2+}	Σcat	CO_3^{2-}	HCO_3^-	Cl^-	⅓PO_4^{3-}	½SO_4^{2-}	Σan	EC	Σsalt	pH
Jul.	262	1.4	1.2	0.6	265	62	22.6	69	2.5	109	265	27.1	17350	9.5
Aug.	480	2.2	1.2	0.4	484	87	34.9	138	2.9	220	483	54.2	34694	10.0
Sep.	371	1.5	1.3	0.6	374	99	23.0	103	3.3	146	374	44.1	28236	9.8
Oct.	196	1.3	0.8	0.4	198	16	31.5	54	2.0	95	198	20.8	13289	9.1

Table 2. Seasonal changes of ion concentrations (mmol/l) in the cell sap of *Suaeda maritima*, with cation sum (Σcat), anion sum (Σan), electronic conductivity (EC, mS/cm), and acidity (pH).

	Na^+	K^+	½Ca^{2+}	½Mg^{2+}	Σcat	HCO_3^-	Cl^-	⅓PO_4^{3-}	½SO_4^{2-}	Σan	EC	pH
Jul.	589	46.8	10.5	39.6	688	9.8	83.4	21.2	125	239	86.3	6.7
Aug.	764	89.5	1.0	61.8	916	13.8	117.0	42.3	110	283	119	6.7
Sep.	851	153.0	5.0	74.2	1083	13.8	193.0	63.5	150	420	141	6.1
Oct.	764	120.0	5.0	90.7	980	15.7	147.0	42.3	100	305	141	6.1

Table 3. Seasonal ecophysiological parameters indicative of the water regime of *Suaeda maritima*. – Osmotic potential (MPα), average transpiration (mg/g·min), root to shoot (based upon fresh weight) and fresh to dry weight ratios, and hydrolysed sugar concentrations (mmol/l).

	osmotic potential	transpiration	root/shoot ratio	wet/dry weight	sugars
Jul.	–2.59	4.70	0.12	4.29	24.7
Aug.	–2.74	6.36	0.13	5.82	17.3
Sep.	–3.25	4.15	0.18	3.69	106.0
Oct.	–2.82	2.89	0.19	2.68	60.2

Methods

Samples of soil and plant material were taken at thirty days intervals during the period July to October 1992. Soil samples were made to be representative of the upper (0-20 cm) soil layer. Determination of pH values was carried out on water-saturated soil paste. In aqueous soil extract have been analysed The concentrations of sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), bicarbonate (HCO_3^-), carbonate (CO_3^{2-}), chlorine (Cl^-), sulphate (SO_4^{2-}) and phosphate (PO_4^{3-}) ions were measured by standard methods. The same ions were also determined in the cell sap of *Suaeda maritima*. Electric conductivity (EC) of aqueous soil extract and cell sap was measured by the conductometric method.

To assess the water regime of *Suaeda maritima,* transpiration intensity (gravimetric method) and osmotic potential of cell sap (cryoscopic method) were measured in three replicates. Microclimatic measurements were simultaneously made. Concentrations of hydrolysed sugars were determined by the colorimetric method of Dubois (1956), while the osmotic potential of ions was calculated according to Acevedo & al. (1979).

Results and discussion

The water regime of *Suaeda maritima* has been assessed under the conditions of its natural habitat, which is characterized by an extremely saline and alkaline soil, quite unsuited for agricultural purposes. However, the plants of *Suaeda maritima* from which samples were taken were well developed, at least as to their vegetative organs, with an average root length of 21.10 ± 4.86 cm, a shoot length of 48.13 ± 4.66 cm, and leaves 3.33 ± 0.31 cm long and 0.37 ± 0.02 cm wide.

Table 1 details the most frequent cations and anions present in the soil, overall salt content, soil EC, and pH. Among cations, sodium was dominant throughout the period of study, while the share of other cations was negligible (0.83-1.25 %). Among anions, sulphates prevailed in quantity, accounting for c. one half of the total, followed by chlorine, carbonate and bicarbonate ions. The high sodium content of the soil solution as well as the presence of bicarbonates and carbonates are the main cause of high alkalinity of the soil, which soil may be characterized as a primary sulphate-chloride sodic solončak.

The ion content of the cell sap (Table 2) shows a much higher salt concentration as compared to the soil, which is due to both passive and active uptake, and to accumulation of ions in vacuoles by active transport so as to increase osmotic pressure. Na^+ was dominant among cations along, which also show active uptake of K^+ and Mg^{2+}, while the Ca^{2+} uptake was not significant. A high Na/Ca ratio is a general feature of halophytes (Marschner & Mix 1973). The Na/K ratio, which peaks at 12.1 at the beginning of the vegetation period, is in good agreement with data of Hajibagheri & Flowers (1989); its decrease in parallel with plant maturity was also observed by Binet (1963). Most frequent among the anions were chlorine, followed by sulphate, phosphate and bicarbonate. A selective uptake of chlorine in preference to sulphate ions is related to their influence on succulence, which is responsible for the dilution of salt concentration in tissues (Adriani 1958).

Transpiration and osmotic potential are very sensitive parameters to describe water regime and indicate the degree of a plant's adaptation to habitat conditions. Average monthly values of transpiration intensity and osmotic potential (Table 3) do not vary considerably during the vegetation period, unlike the micro-climatic factors that influence them, as e.g. average daily temperature and relative humidity which ranged from 28.58°C and 41.16 % in August to 11.3°C and 57.02 % in October, respectively. Fresh/dry weight ratio peaked in August, the hottest and driest month. Irrespective of an increased ion uptake, resulting in greater succulence, no significant decrease of osmotic potential was noted (only –5.47 % from July to August). The root/shoot weight ratio increased all along the vegetation period, due to increased water uptake needed to com-

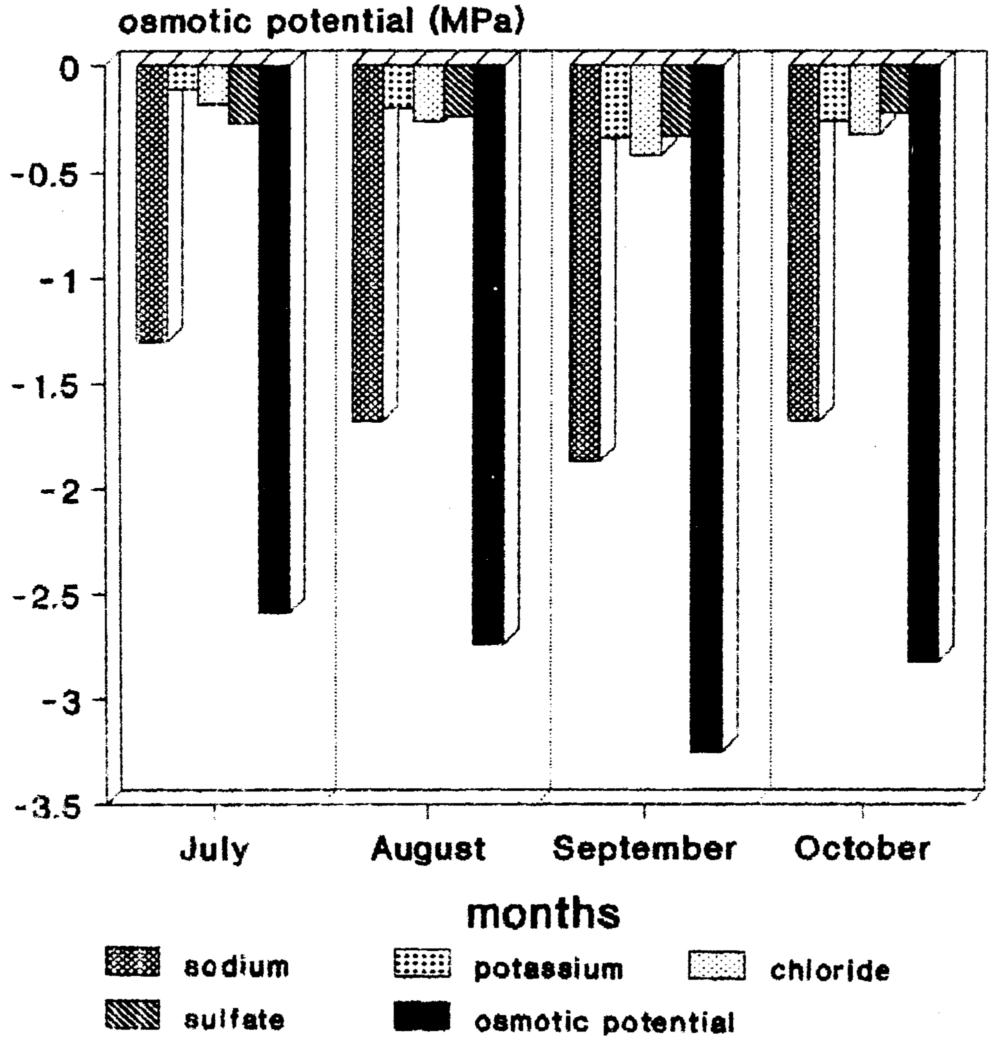

Fig. 1. Seasonal contribution of different ions to the total osmotic potential of *Suaeda maritima*.

pensate shoot dehydration through ageing and salt accumulation. The highest concentration of hydrolysed sugars was recorded in September, along with the lowermost values for osmotic potential and highest sulphate concentrations in the cell sap. This corresponds with an increase of xerophytic features and correlated decrease, by 36.6 %, of the fresh/dry weight ratio.

The ions mainly participating in the osmotic potential of *Suaeda maritima* (Fig. 1) can be ranked as follows: Na > Cl > SO > K. The correlation between osmotic potential and sodium content in the cell sap is positive, strong, statistically significant ($r = 0.924$). The proportion in which these ions contribute to the osmotic potential (71.81 % to 91.07 %) is of the same order of magnitude as had been found by Albert & Popp (1978).

The role played by sodium and chlorine in the osmotic adjustment of halophytic plants is well known. Potassium, important for turgor maintenance, is present in the cells mainly in the form of chlorides, nitrates, malates and other salts (MacRobbie 1977). Besides participating in osmotic regulation, sulphates have an important role in the formation of high-weight protein fractions. These proteins were found in the shoots of *Suaeda maritima* under salt stress conditions (Billard & al. 1982).

Conclusion

Under the conditions of high sulphate-chloride-sodic salinity prevailing in its natural habitat, *Suaeda maritima* shows a stable water regime. Its low osmotic potential values are indicative of osmotic adaptations in response to increased salt concentration in the soil. Na^+, Cl^-, SO_4^{2-}, and K^+ ions contribute for the larger part to the osmotic potential. The most remarkable uptake rate, as compared to their concentration in the soil solution, was measured for chlorine and particularly potassium ions, which is explained by their specific role in halophyte metabolism.

References

Acevedo, E., Fereres, E., Hsiao, T. C. & Henderson, D. W. 1979: Diurnal growth trends, water potential and osmotic adjustment of maize and sorghum leaves in the field. – Pl. Physiol. (Lancaster) **64:** 476-480.

Adriani, M. J. 1958: Halophyten. – Pp. 709-736 in: Ruhland, W. (ed.), Handbuch der Pflanzenphysiologie, **4.** – Berlin.

Albert, R. & Popp, M. 1978: Zur Rolle der löslichen Kohlenhydrate in Halophyten des Neusiedlersee-Gebietes (Österreich). – Oecol. Pl. **13:** 27-42.

Billard, J. P., Binet, P. & Boucaud, J. 1982: Electrophoretic modification of soluble leaf proteins of *Suaeda maritima* var. *macrocarpa, Atriplex hortensis* and *Phaseolus vulgaris* in relation to the NaCl content of the culture medium. – Canad. J. Bot. **60:** 1590-1595.

Binet, P. 1963: Le sodium et le potassium chez *Suaeda vulgaris.* – Physiol. Pl. (Lancaster) **16:** 615-622.

Dubois, M. 1956: Colorimetric methods for determination of sugars and related substances. – Analytical Chem. **28:** 350-356.

Flowers, T. J. & Yeo, A. R. 1986: Ion relations of plants under drought and salinity. – Austral. J. Pl. Physiol. **13:** 75-91.

Greenway, H. & Munns, R. 1980: Mechanisms of salt tolerance in non halophytes. – Annual Rev. Pl. Physiol. **31:** 149-190.

Hajibagheri, M. A. & Flowers, T. J. 1989: X-ray microanalysis of ion distribution within root cortical cells of the halophyte *Suaeda maritima* (L.) Dum. – Planta **177:** 131-134.

MacRobbie, E. A. C. 1977: Functions of ion transport in plant cells and tissues. – MTP Int. Review Sci., Biochem. **13:** 211-247.

Marschner, H. & Mix, G. 1973: Einfluss von Natriumchlorid und Mycostatin auf den Mineralstoffgehalt im Blattgewebe und die Feinstruktur der Chloroplasten. – Z. Pflanzenernähr. Bodenk. **136:** 203-219.

McKree, K. J. 1986: Whole carbon balance during osmotic adjustment to drought and salinity stress. – Austral. J. Pl. Physiol. **13:** 33-43.

Munns, R., Greenway, H. & Kirst, G. O. 1983: Halotolerant eukaryotes. – Pp. 59-135 in: Pirson, A. & Zimmermann, M. H. (ed.), Encyclopedia of plant physiology, ser. 2, **12C.** – Berlin, etc.

Weisel, Y. 1972: Biology of halophytes. A series of monographs, texts and treatises. – New York & London.

Wyn Jones, R. G., Brady, C. J. & Speirs, J. 1979: Ionic and osmotic relations in plant cells. – Pp. 63-103 in: Laidman, D. L. & Wyn Jones, R. G. (ed.), Recent advances in the biochemistry of cereals. – London & New York.

Address of the authors:
Zora Dajić, Mirjana Stajković & Miodrag Jakovljević, Faculty of Agriculture, Department of Botany, Nemanjina 6, YU-11080 Beograd, Yugoslavia.