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Effects of Ion Uptake for Salt Tolerance in Several Mediterranean Halophytes

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Abstract: The patterns of ion uptake were analysed in three dicotyledonous (*Arthrocnemum macrostachyum*, *Sarcocornia fruticosa* and *Inula crithmoides*) and two monocotyledonous (*Juncus acutus* and *J. maritimus*) halophytes, collected from a salt marsh in SE Spain. The experimental design included four plots in different positions within the marsh, and three sampling periods corresponding to spring, summer and autumn 2011. Electric conductivity, pH, and Na^+, K^+, Ca^{2+}, Mg^{2+} and Cl^- contents were determined in saturated soil extracts. In plants, the same ions were extracted in boiling water. In soil samples, spatial variation in the measured parameters among plots was higher than the seasonal variation within plots, whereas in plants significant differences in ion contents were detected only between species, but not between plots or sampling seasons for a given species. The dicot species under study are Na^+ and Cl^- accumulators, showing significant higher levels of these ions than the monocot taxa, but a direct correlation between ion content in soil and plants could be not established.

Keywords: halophytes, soil EC, Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-

Introduction. The study of plant responses to salt stress is very interesting from academic and practical points of view, since salinity is, together with drought, the most important environmental stress factor affecting crop yields in agriculture and plant distribution in nature. However, very little is known about salt tolerance mechanisms in plants adapted to high soil salinity in nature – the halophytes.

Aims and objectives. This study attempts to establish the contribution of ion accumulation to salt tolerance of several Mediterranean halophytes in their natural habitat.

Materials and methods. Four experimental plots were defined in a littoral salt marsh near Elche (SE Spain), and soil samples were collected in spring, summer, and autumn 2011. Simultaneously, leaves of five halophytes (*Juncus acutus, J. maritimus*, *Arthrocnemum macrostachyum*, *Sarcocornia fruticosa*, and *Inula crithmoides*) were sampled from five individual plants per species. Soil electric conductivity (EC), pH and ionic content were analysed in saturated paste extracts (USSL Staff, 1954). Ions were extracted in boiling water from plant material (Weimberg, 1987), and quantified by flame photometry (Na^+, K^+) or by atomic absorption spectrometry (Ca^{2+}, Mg^{2+}). Chlorides were determined by precipitation with $AgNO_3$.

Results and Discussion. Clear spatial differences in soil salinity were detected, with the two plots located in the central area of salt marsh (plots 2 and 3) showing much higher EC values and ion contents, while seasonal differences in each plot were, in general, relatively small (Fig. 1, and data not shown). These spatial differences are reflected in the distribution of the investigated species: *J. acutus*, which is the least salt-tolerant, was present only on the plots with lower salinity (1 and 4) located on the border areas of the salt marsh.

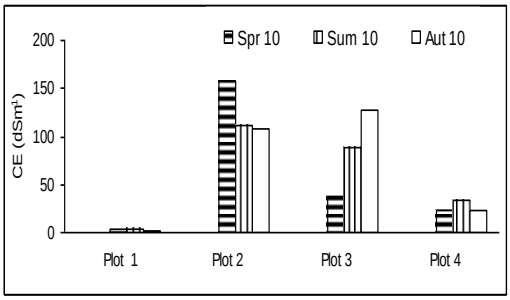

Fig. 1. Electric conductivity (CE) in soil saturated extracts: seasonal variations in the four plots defined in the salt marsh

Marked differences in ion levels were observed between plant species: the most salt-tolerant taxa – *A. macrostachyum, S. fruticosa* and *I. crithmoides*, all dicotyledonous succulent halophytes – proved to be accumulators of Na^+ and Cl^-, which reached very high levels independently of the ion contents in the soil. Toxic ions accumulated to much lower extent in the two *Juncus* species (monocotyledonous), which are less salt-tolerant (Fig. 2).

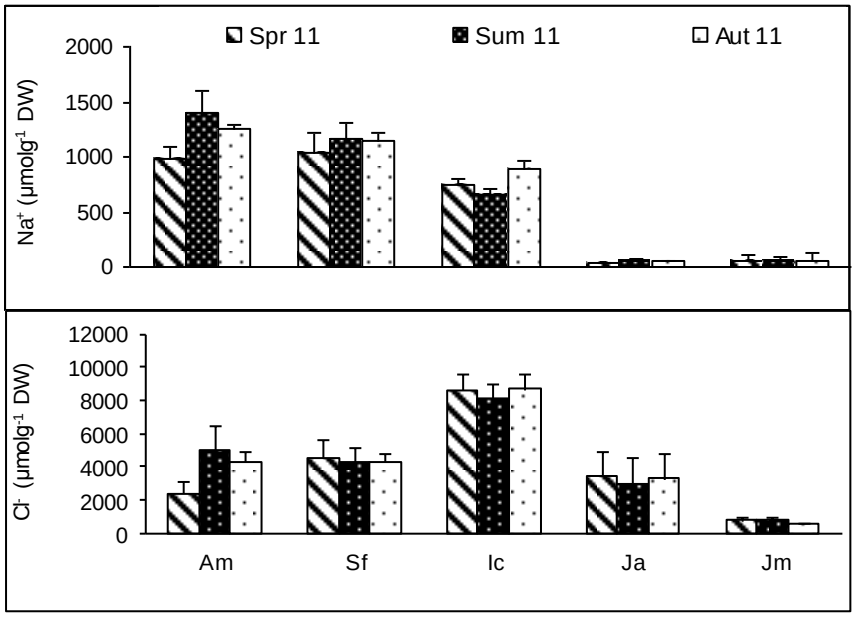

Fig. 2. Na^+ and Cl^- contents in *Arthrocnemum macrostachyum* (Am), *Sarcocornia fruticosa* (Sf), *Inula crithmoides* (Ic), *Juncus acutus* (Ja), *and J. maritimus* (Jm).

Conclusion

Our results suggest that active uptake and accumulation of toxic ions in the aerial parts of the plants are an important mechanism for salt tolerance. This mechanism is especially efficient in the highly tolerant succulent dicotyledonous halophytes.

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