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How does the root of *Salicornia herbacea* response to salinity in comparison to the shoot?

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Abstract. Despite the advances in our understanding of plant salt tolerance there still remain open questions. The aim of this study was to determine ion accumulation in root and shoot of *salicornia herbacea.* Seeds of *S. herbacea* were planted in greenhouse condition. Salinity treatments at 6 levels and 2 salts were applied at 2 months. Our observation about ion content in root and shoot showed that K^+ and Na^+ were higher in shoot and Na_2SO_4 salt, whilst Ca^{2+} content was more in root and NaCl salt. Also, Na^+ content increased with salinity increasing, but K^+, Mg^{2+} and Ca^{2+} decreased. In fact, there is a competition among Na^+, Ca^{2+} and K^+ absorption at different salt concentration. The ions content at different salt followed the order of $Na^+ > Ca^{2+} > K^+$. In general, *S. herbacea* tolerates different kinds of salinity via accumalting different ions and distrbuting them in different organs at each kind of salt.

Keywords: *Salicornia herbacea*, ion disturbance, plant organs, salt stress

1. Introduction

It is well known that under salt stress conditions, plants change physiologically and morphologically to tolerate salinity (Schmidhalter *et al*., 1999). Plants growing in saline environments have different mechanisms of taking up and distributing salt ions (Tan et al. 2003; Greenway et al. 1983). Almost all micro- and macronutrient contents decrease in the roots and shoots with increasing salt concentration in the growth medium. Shoot growth was more strongly influenced by salinity than root growth which resulted in an increase of the root/shoot ratio of the salinity exposed plants. This indicates a shift in biomass accumulation to enhanced root growth which has often been interpreted as an adaptation of plants to an environmental stress that allows the plant to have greater to water and nutrient resources (Wang et al. 2006; Yu et al. 2005). However, this reduction in shoot growth and to a lesser extent root growth has been observed in other plant species and was interpreted as an osmotic effect of the saline solution in the soil (Jie et al. 2008). Whereas, there is little data on ion changes in shoot and root of plants. Therefore, this study was done in order to determine ion accumulation at different organs of *Salicornia herbacea*.

2. Materials and Methods

Salicornia herbacea L. a halophyte salt includer species is particularly well adapted to arid, semi-arid and salt-affected areas of Iran. The study was carried out at Karaj/Iran through March to August 2008. The plants were grown in a greenhouse on 28/21 °C day/night temperatures, 65-85% relative humidity of air and planted in Plastic pods with the Silica sand bed. Plants were nitrified with Hoagland's nutrient solution for 6 months (Hoagland and Arnon, 1950). Then, Salinity treatment consisted of 0 (control), 100, 200, 300, 400, 500 mM of NaCl and Na_2SO_4 separately. The plants were harvested after 6 weeks of treatment. Root and shoot tissues were harvested separately. Na^+, k^+, Mg^{2+} and Ca^{2+} were determined in the extract by an inductively coupled plasma atomic emission spectrometer (ICP) (Navarro et al. 2006). Ratios of ions in different organs were calculated. ANOVA and Duncan test were used for statistical analysis.

3. Results

Table 1 indicates that ions content vary significantly at different plant part, salt type and concentration. Ratios of ions in *S. herbacea* and shoot/root ratio of ions change statistically. Of course, Mg^{2+} at different salt type and plant part, shoot/ root ratio of Ca^{2+} and K^+ remained unchanged.

Table1. ANOVA Results of ion changes in *S. herbacea* organs

Sources \ Dependent Variable	Ca^{2+}	Mg^{2+}	K^+	Na+
Salt type	26.4^{**}	0.063^{ns}	19.3^{**}	14.06^{**}
Plant part	1555^{**}	0.032^{ns}	334^{**}	587^{**}
Salt concentration	27.8^{**}	29.2^{**}	95.5^{**}	26.7^{**}
Sources \ Dependent Variable	**Ca^{2+} (shoot/root)**	**Mg^{2+} (shoot/root)**	**K^+ (shoot/root)**	**Na^+ (shoot/root)**
Salt type	4.1^{ns}	73.9^{**}	0.002^{ns}	14.3^{**}
Salt concentration	5.74^{**}	19.7^{**}	4.9^{**}	3.01^{*}
Sources \ Dependent Variable	**Na^+/K^+**	**Mg^{2+}/Ca^{2+}**	**Ca^{2+}/K^+**	**Na^+/Ca^{2+}**
Salt type	6.37^{*}	7.02^{*}	9.2^{**}	9.6^{**}
Plant part	28.8^{**}	642.1^{**}	209.6^{**}	493.2^{**}
Salt concentration	72.9^{**}	2.32^{ns}	9.8^{**}	11.04^{**}

- Numbers shows F value , * $p < 0.05$, ** $p< 0.01$, ^{ns} non significant

According to the table (2) Ca^{2+} content was more in root and at NaCl than shoot and Na_2SO_4, whilst K^+ and Na^+ were higher in root and at Na_2SO_4. Mg did not change significantly in different organs or salts.

Table 2. Results of Duncan test of ions changes in different plant organs and salt type

Dependent Variable	Plant part	Mean	Salt type	Mean	Dependent Variable	Plant part	Mean	Salt type	Mean
Ca^{2+}	shoot	693 b*	NaCl	1173 a	K^+	shoot	750 a	NaCl	532.7 b
	root	1343 a	Na_2SO_4	993.3 b		root	399 b	Na_2SO_4	617.1 a
Mg^{2+}	shoot	128 a	NaCl	128.5 a	Na^+	shoot	4491 a	NaCl	3753 b
	root	145 a	Na_2SO_4	127.7 a		root	1480 b	Na_2SO_4	3218 a

*:Letters indicate significant differences between treatments

Table 3 shows that Na^+/K^+, Mg^{2+}/Ca^{2+}, Na^+/Ca^{2+} ratios were higher in shoots than roots. Interestingly, Na^+/Ca^{2+} ratio in shoot was 12.1 whilst it was only 0.9 in root. Inversely, Ca^{2+} was more in root than K^+, whilst Ca^{2+}/K^+ ratio was only 0.57 in shoot. Also, the ions content at different salt followed the order of $Na^+ > Ca^{2+} > K^+$.

Table 3. Results of Duncan test of ions ratio changes in different plant organs and salt type

Dependent Variable	Plant part	Mean	Salt type	Mean	Dependent Variable	Plant part	Mean	Salt type	Mean
Na^+/K^+	shoot	7.01 a	NaCl	5.73 b	Ca^{2+}/K^+	shoot	0.57 b	NaCl	2.6 b
	root	5.02 b	Na_2SO_4	6.55 a		root	5.78 a	Na_2SO_4	3.7 a
Mg^{2+}/Ca^{2+}	shoot	0.33 a	NaCl	0.21 a	Na^+/Ca^{2+}	shoot	12.1 a	NaCl	7.2 a
	root	0.07 b	Na_2SO_4	0.19 b		root	0.9 b	Na_2SO_4	5.6 b

K^+, Mg^{2+} and Ca^{2+} decreased with salinity increasing at all treatments, whilst Na^+ increased when growth medium salinity increased. On the other hand, control treatment (non saline water) had the most content of K^+, Mg^{2+} and Ca^{2+} and the lowest Na^+ (figure 1).

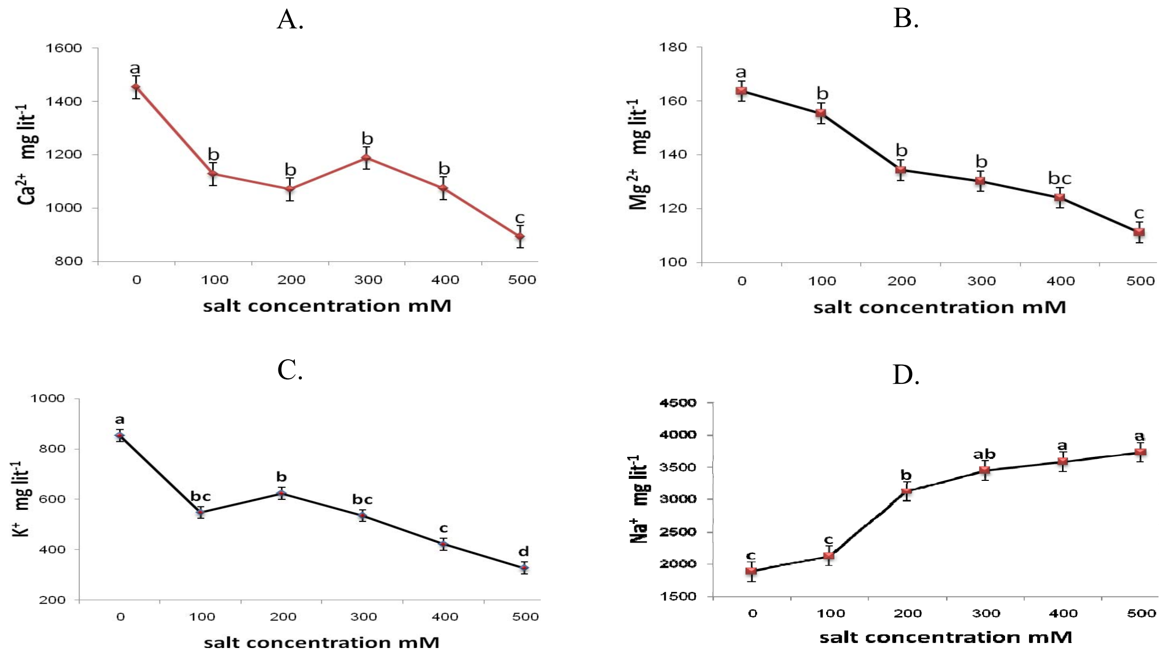

Fig.1: K^+, Mg^{2+}, Ca^{2+} and Na^+ changes at different salinity concentrations. Bars represent mean ± standard error. Different letters represent a significant difference $P < 0.05$ between treatments.

Figure 2.A and B indicates that there is a competition among Na^+, Ca^{2+} and K^+ absorption at different salt concentration. Increasing of Na^+ is together with decreasing of Ca^{2+} and K^+. Also, figure 2-C shows that K^+ reduction occurs faster than Ca^{2+} when environment salinity increases. Moreover, according to figure 2-D, Mg^{2+} play more important role against Ca^{2+} at low salinity in *S. herbacea*.

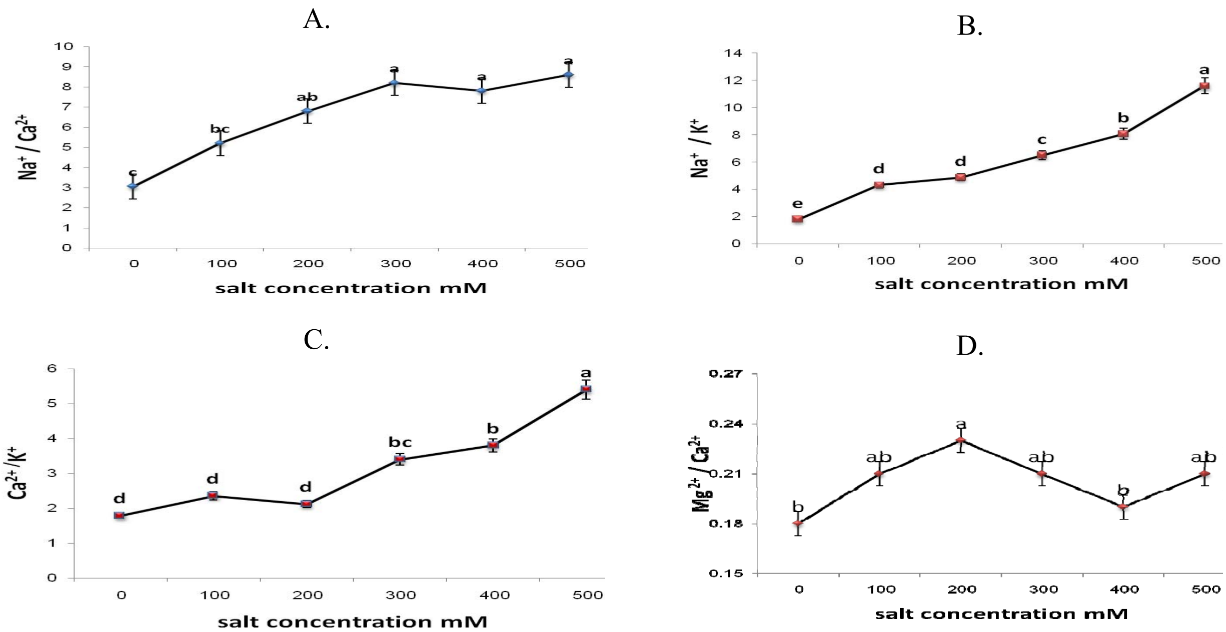

Fig.2: Duncan test ions ratio at different salinity concentrations. Bars represent mean ± standard error. Different letters represent a significant difference $P < 0.05$ between treatments.

Figure 3 illustrates that shoot/root ratios of ions change with salinity increasing and vary at different salt type. shoot/root ratios of Ca^{2+}, Mg^{2+} and Na^+ were higher at all NaCl concentrations than Na_2SO_4.

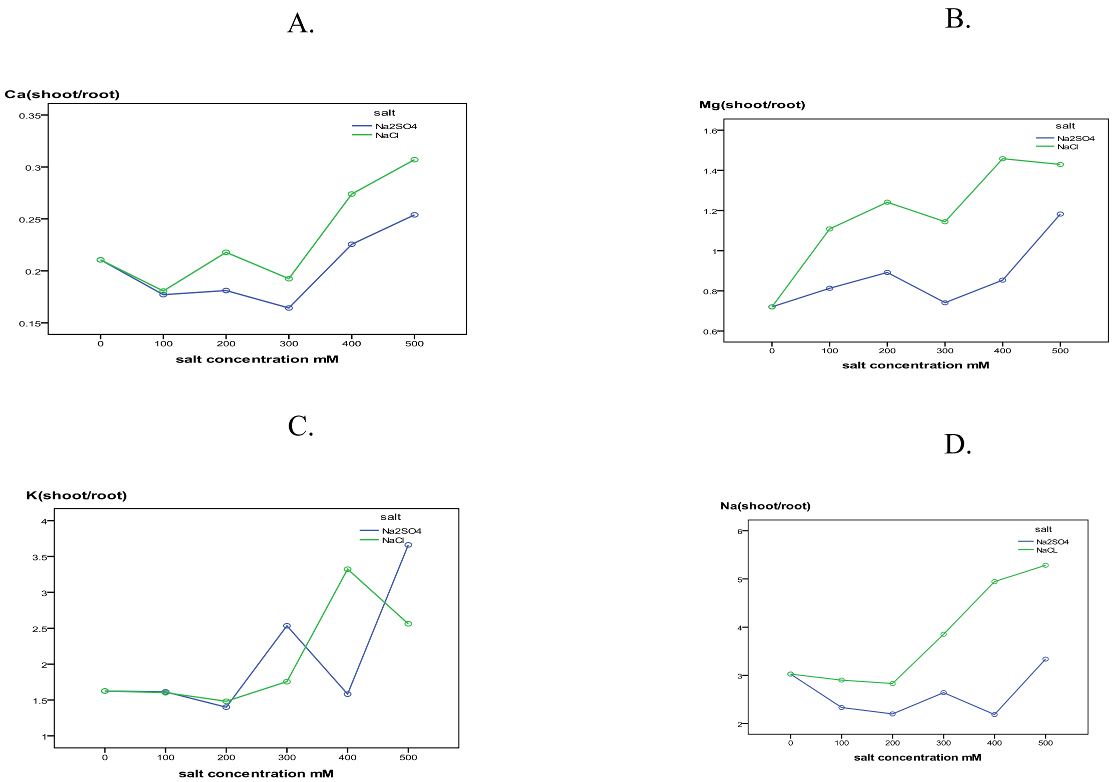

Fig. 3: shoot/root ratio of ions changes at different salt type and concentration.

4. Discussion

Increasing of Na^+ and decreasing of Ca^{2+}, Mg^{2+} and K^+ that has been resulted in this study, has been reported by other scientists (Duan et al. 2007; Khan et al. 2001; Unger, 1987). Nobel and Bronqnell (1984) showed that Sodium ion can be helpful for regulating osmotic potential and water balace in plants.

A lot of ions are absorbed by halophytes under salt stress and the ions get accumulated in different parts depending on the plant salt protection mechanisms (Breckle, 1995). In our study with *S. herbacea* Na^+ ions dominated and these were accumulated mostly in the shoot. Zhao and Feng (2001) and Duan et al. (2007) reported similar results in *Suaeda salsa*. Calcium and Magnesium concentrations were extremely low in shoots of plants grown at high salinity agreeing with the results found for other halophytes (Gul et al. 2000; Naidoo et al. 1990; Glenn and Oleary, 1984). Our results show that Na^+ absorption is together with Ca^{2+}, Mg^{2+} and K^+ repulsing. El-Fouly *et al*., (2002) and Salama *et al*., (2004) found that high salt concentration in the root growth medium limit the uptake of nutrients in the different organs.

In general, *S. herbacea* tolerates different kinds of salinity via accumalting different ions and distrbuting them in different organs at each kind of salt

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