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Original article

Effect of water salinity on biomass, ash content and some ions concentration in pickleweed (*Salicornia bigelovii* Torr.)

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Extended abstract

Introduction

In regions with severe limitation of fresh water, salinity poses a serious threat to agriculture production due to its toxicity to most plants. Salinity tolerant plants that can survive and grow in high-salinity conditions are called halophytes. Halophyte cultivation has the potential to restore saline environments, provide for global food demands, produce medicine and biofuels, and conserve fresh water. Two approaches are presented to developing tolerant plants of seawater salinity; the first is increasing tolerance of conventional plants, and the second is choice from the large pool of halophytes, which already have the requisite salt tolerance. The difference between the upper limit of salt tolerance of conventional plants and required tolerance level to seawater salinity is huge. It has been shown that Salicornia spp. has the potential to tolerate salinity of seawater. Salicornia is a genus of succulent, halophyte flowering plants in the family Amaranthaceae that grow in salt marshes, on beaches, and among mangroves. Pickleweed (Salicornia bigelovii Torr.) is an obligate halophyte that has been considered as a promising plant due to the tolerance to hypersaline water and economic values such as forage production, oilseed production and fresh consumption. This study evaluated the response of Salicornia bigelovii to different water salinity treatments, determines its salt tolerance threshold and shows trend of the accumulation of Ca^{2+}, Cl^{-}, Na^{+} and K^{+} ions in the plant shoots.

Materials and methods

This experiment was conducted as a completely randomized design with 4 replicates in the greenhouse of the National Salinity Research Center, Yazd, Iran. Saline water treatments included 2, 5, 8, 11, 14 and 17 dS m^{-1}, which were prepared using dilution of Persian Gulf water. Salinity treatments were applied as irrigation of pickleweed (Salicornia bigelovii) plants with related saline water treatments. The 10 uniform seeds were sown in pots and were kept in a controlled environment with 26/18 °C (±3) day/night temperature regimes. The 84 days plants were harvested and were immediately transferred to the laboratory. Fresh and dry weight, dry matter, ash content and concentration of calcium (Ca^{2+}), chloride (Cl^{-}), sodium (Na^{+}) and potassium (K^{+}) were measured in shoots. Data were subjected to analysis of variance, and the means were compared using LSD at 5% probability level. Response cure was used to determine the threshold level of reduction after reaching the peak.

Results and discussion

The results showed that salinity treatment was significant on all traits, except dry matter percent and potassium concentration. The results showed that increasing salinity up to 8 dS m^{-1} increased fresh and

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dry weight, however higher salinity levels were associated with reduction. The threshold level of reduction after reaching to the peak were 8.65 and 7.01 dS m^{-1} for fresh and dry weight, respectively. The amounts of reduction in fresh weight in 2, 5, 11, 14 and 17 dS m^{-1} treatments compared to 8 dS m^{-1} treatment were 26.9%, 9.5%, 12.0%, 20.0% and 35.8%, respectively. These reductions were 23.4%, 20.7%, 27.4%, 38.9% and 41.7%, respectively in dry weight. With increasing salinity of water, the ash content of shoots had an ascending and significant trend. The lowest and the highest shoot ash were related to 2 and 17 dS m^{-1} water salinity, by 24.8% and 41.3%, respectively. As salinity was increased, the concentration of chlorine and sodium in shoots were enhanced, while the concentration of calcium and potassium were reduced. Correlation and stepwise regression analyses revealed that concentration of calcium and potassium were the most important traits in salinity tolerance of salicornia. It seems that salinity tolerance in salicornia occurs by osmotic regulation as the accumulation of salts in its tissue.

Conclusions

According to the results of this study, it can be concluded that the capability of ions accumulation strengthens the phytoremediation ability of salicornia, however increasing in ash content could have a negative effect on the forage value of the plant. Therefore, determining the nutritional value of salicornia and feed analyzing in the presence of livestock require further evaluation.

Keywords: Forage, Halophyte, Osmotic regulation, Phytoremediation, Seawater

Table 1. Soil (Saturated extract) and water chemical properties used in the experiment

	EC (dS m^{-1})	pH	Na^+	Mg^{2+}	Ca^{2+}	Cl^-	HCO_3^-	SO_4^{2-}	SAR
			meq l^{-1}						
Soil	31.3	7.01	246.18	33.16	60.24	276.68	1.49	61.41	36.02
Water	60.20	8.19	526.33	127.17	24.39	617.45	1.80	-	60.46

EC, Electrical conductivity; SAR, Sodium adsorption ratio

Table 2. Mean of squres for the effect of salinity on fresh weight (FW), dry weight (DW), dry matter percentage (DMp), ash content, calcium (Ca), chloride (Cl), sodium (Na) and potasium (K)of pickleweed (*Salicornia bigelovii*) shoot

Source of variation	Df	FW	DW	DMp	Ash	Ca^{2+}	Cl^-	Na^+	K^+
		---------- (g) ---------		---------- (%)----------					
Salinity	5	47.318**	1.277**	9.870^{ns}	133.026**	0.041**	29.472**	21.008**	0.113^{ns}
Error	18	8.436	0.279	3.656	3.150	0.005	1.589	0.721	0.085
C.V. (%)		*13.065*	*18.779*	*15.051*	*5.087*	*18.772*	*9.164*	*10.696*	*21.314*

ns: non-significant; ** significant at 1% probability level.

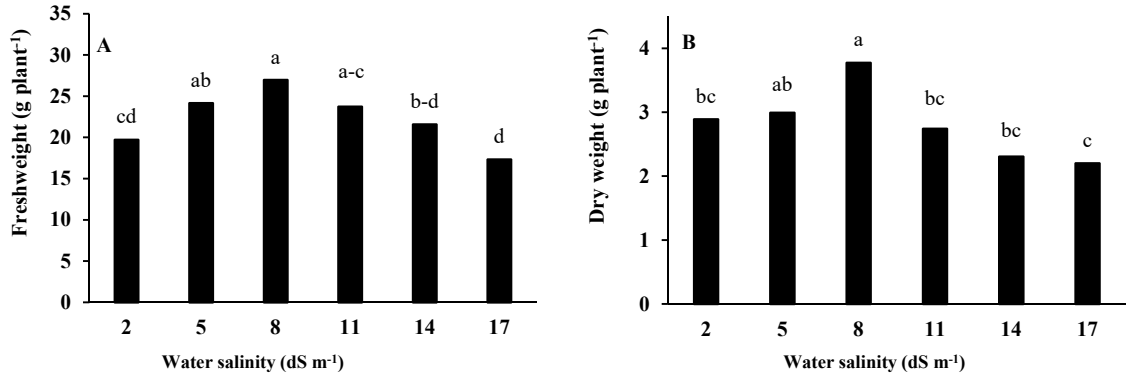

Fig. 1. Comparison of mean fresh weight (A) and dry weight (B) of pickleweed (Salicornia bigelovii) under different saline water treatments. The column with similar letter had no significant difference based on LSD 0.05.

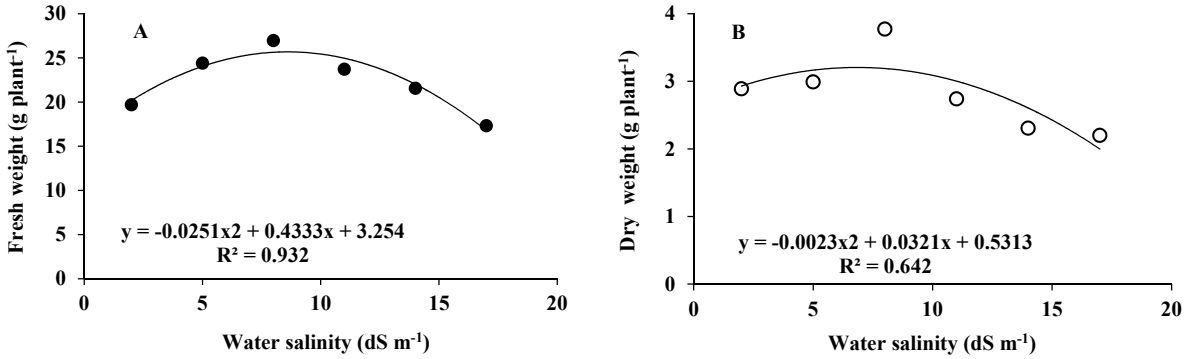

Fig. 2. Response cure for trend of changes in fresh weight (A) and dry weight (B) of pickleweed (*Salicornia bigelovii*) in different saline water levels

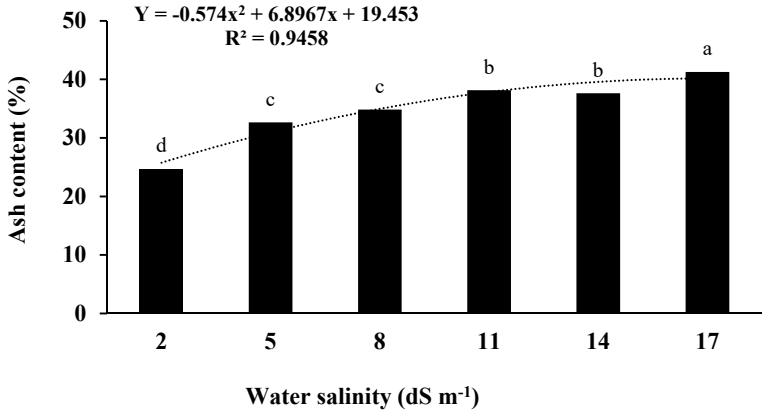

Fig. 3. Comparison of ash percent of pickleweed (Salicornia bigelovii) under different saline water treatments. The column with similar letter had no significant difference based on LSD 0.05.

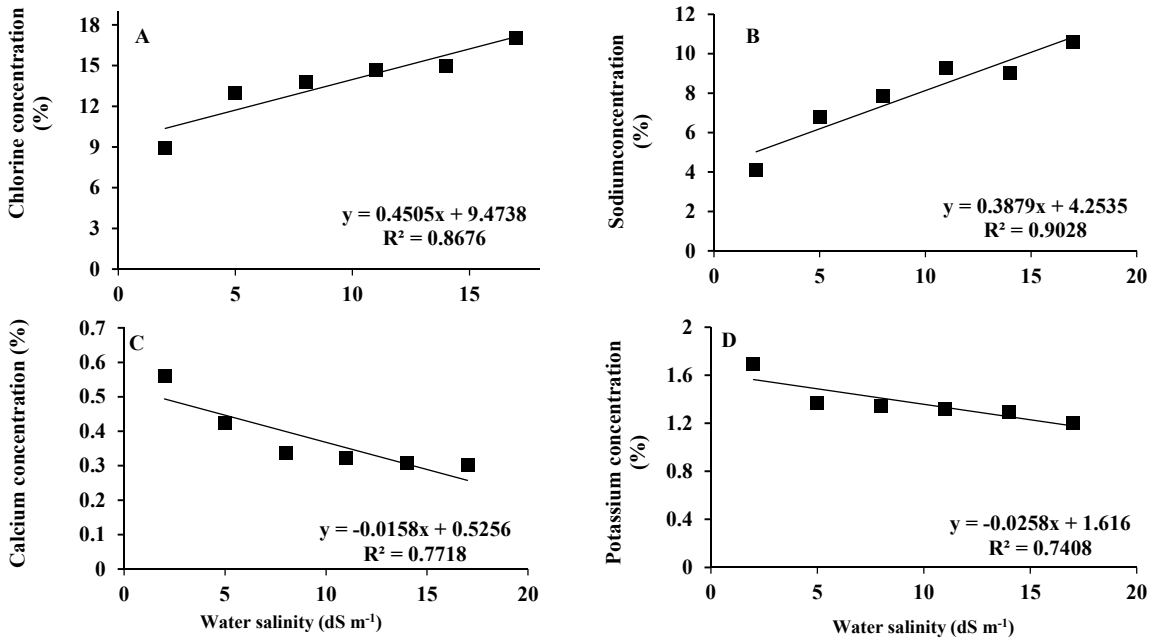

Fig. 4. The response of concentration of Cl^- (A), Na^+(B), Ca^{2+}(C) and K^+(D) ions in pickleweed (*Salicornia bigelovii*) shoot to different saline water levels

Table 3. The results of correlation of the traits with fresh and dry weight of pickleweed (*Salicornia bigelovii*)

	FW	DW	DMp	Ash	Ca^{2+}	Cl^-	Na^+
DW	0.836**						
DMp	-0.101ns	0.786**					
Ash	0.010ns	-0.194ns	-0.374ns				
Ca^{2+}	0.563*	0.602*	0.741**	-0.716**			
Cl^-	0.060ns	-0.085ns	-0.285ns	0.961**	-0.702**		
Na^+	-0.019ns	-0.18ns	-0.330ns	0.978**	-0.685**	0.961**	
K^+	-0.074ns	0.621*	0.237ns	-0.359ns	0.082ns	-0.418*	-0.470*

ns: non-significant; * significant at 5% probability level.
FW: Fresh weight, DW: dry weight, DMp: dry matter percentage.

Table 4. The results of stepwise regression analysis for determining the most effective traits on fresh weigh and dry weight of pickleweed (*Salicornia bigelovii*)

	Step	Trait	Partial R^2§	Model R^2 §	P Value
Fresh weight	**1**	**Ca^{2+} concentration**	0.9801	0.9801	0.003**
	2	**K^+ concentration**	0.0080	0.9881	0.043*
Dry weight	**1**	**Ca^{2+} concentration**	0.9702	0.9752	0.001**
	2	**K^+ concentration**	0.0153	0.9855	0.027*

.* and ** significant at 5% and 1% probability levels, respectively

§ The partial R^2 relates to the trait in each step and the model R^2 relates to all traits until that step.