International Conference on Industrial Technology and Management Science (ITMS 2015)

The Adaptation of *Suaeda physophora* Seedlings to Salinity and Drought Environments

W.W. Zhao, T.T. Fu, F.X. Wang, Y.G. Xu & J. Song*
Key Laboratory of Plant Stress, College of Life Science, Shandong Normal University, Jinan 250014, China
* author for correspondence

ABSTRACT: We investigated the effect of combined salinity and drought stress on ion accumulation, membrane permeability in leaves, and seedling survival and shoot dry weight of *Suaeda physophora* seedlings after they were rewatered. The results showed that drought stress increased leaf Na^+ and Cl^- content, especially at 400mmol L^{-1} NaCl pretreatment, while drought treatment had no effect on leaf K^+ content after seedlings were pretreated with either 1 or 400mmol L^{-1} NaCl. Shoot dry weight of seedlings decreased during drought treatment compared to control (without drought treatment) regardless the concentrations of salinity after seedlings were rewatered. Drought treatment had less adverse effect on the seedling and leaf survival in seedlings pretreated at 400mmol L^{-1} NaCl than at 1 mmol L^{-1} NaCl after seedlings were rewatered. The present results indicate that seedlings of *S. physophora* pretreated with salinity can increase seedling survival, and this can help them to adapt to combined salinity and drought stress in arid areas.
KEYWORD: *Suaeda physophora*; Salinity; Drought; Shoot dry weight

1 INTRODUCTION

Drought and salinization are two major problems which affect the global environment and economic development. *Suaeda physophora* Pall. is leaf-succulent euhalophytic shrub growing in highly salinized lands. The species is common in saline lands or in the Zhunger Basin, which is located in Xinjiang, a northwest province of China. Annual evaporation is 10 times more than annual precipitation in this region, and it is one of the driest regions in the Eurasian continent (Song et al. 2006a). The percentage of unsaturated fatty acid in seed oil of *S. physophora* was 96%, in which linoleic acid was about 75% (Mu et al. 2006). Therefore, the species can be used in saline agriculture. The species has high salt tolerance during stages of seed germination and seedling growth (Wang et al. 2005; Song et al. 2006a,b). Euhalophytes always accumulate high concentration of inorganic ions to lower osmotic potential, thus they can absorb water from saline soils to ensure growth (Song, et al. 2006a; Liu et al. 2010). *S. Physophora* is a typical euhalophyte in arid areas (Song et al. 2006a,b). However, the mechanism how the species adapt to combined salinity and drought stress is unclear.

2 MATERIALS AND METHODS

2.1 *Plant material*

Seeds were collected from plants in Xinjiang province of northwest China in October 2012. Dry seeds were stored in a refrigerator at < 4℃ before being used.

2.2.1 *Plant culture and experimental design*

Seeds of *S. physophora* were sown in plastic pots filled with river sand. Nutrient solutions of a fifth concentration of Hoagland were supplied dairy, and the pH was adjusted to 6.6 ± 0.1 with KOH and H_2SO_4. The amount of 150ml nutrient solutions was supplied every day, an amount that flushed the drained pots. Ten seedlings with 5 to 6 leaves were left in each pot. Seedlings with 8 to 9 leaves were treated with 1mmol L^{-1} (as control) or 400mmol L^{-1} NaCl. To avoid osmotic shock, 400mmol L^{-1}NaCl was applied gradually by adding 50mmol L^{-1}per day. Two weeks after the final addition of NaCl, 3 pots were watered as control, and the other 3 pots were not watered at 1 or 400mmol L^{-1} NaCl. When most of the seedlings wilted (7days for 1mmol L^{-1} NaCl treatment, and 14days for 400mmol L^{-1} NaCl treatment), ion content and relative conductivity in leaves were determined. Meanwhile, wilted seedlings which were not watered were rewatered with original solutions for another 8days. Then seedling and leaf survival and shoot dry weight were determined.

2.2.2 *Determination of ion content*

The leaves were cleaned with distilled water, and 0.15g fresh sample was boiled in distilled water for 12h. After the solution was filtered, the concentrations of Na^+ and K^+ were determined by flame photometer (Flame Photometer 410, Sherwood Scientific Ltd, Cambridge, UK), Cl^- content was determined by ion-chromatographic analyzer (ICS-1100 Ion-chromatographic Analyzer, Thermofisher Scientic Company, USA).

2.2.3 *Determination of relative conductivity*

A 0.15g fresh leaves were washed with double distilled water, and relative conductivity was determined as described by Leul and Zhou (1999).

2.2.4 *Seedling and leaf survival after seedlings were rewatered*

Seedling and leaf survival percentage were determined based on the number that survived during the combined salinity and drought stress, and calculated according to the formula as follows:

Leaf survival = $n / m \times 100$

Seedling survival = $d / f \times 100$

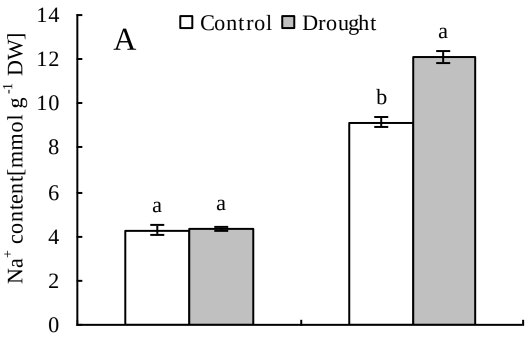
Where n was the leaf survival number after seedlings were rewatered, and m was the total leaf number; d was the seedling survival number after seedlings were rewatered, and f was the total seedling number.

2.2.5 *Shoot dry weight after seedlings were rewatered*

At the end of the study, shoots were harvested from each of six replicate pots at both concentrations of NaCl. The shoots were air-dried and weighed.

2.2.6 *Statistical analysis*

Data were subjected to a Two-way ANOVA using the SAS 6.12 software. Treatment means were compared by LSD at P = 0.05.



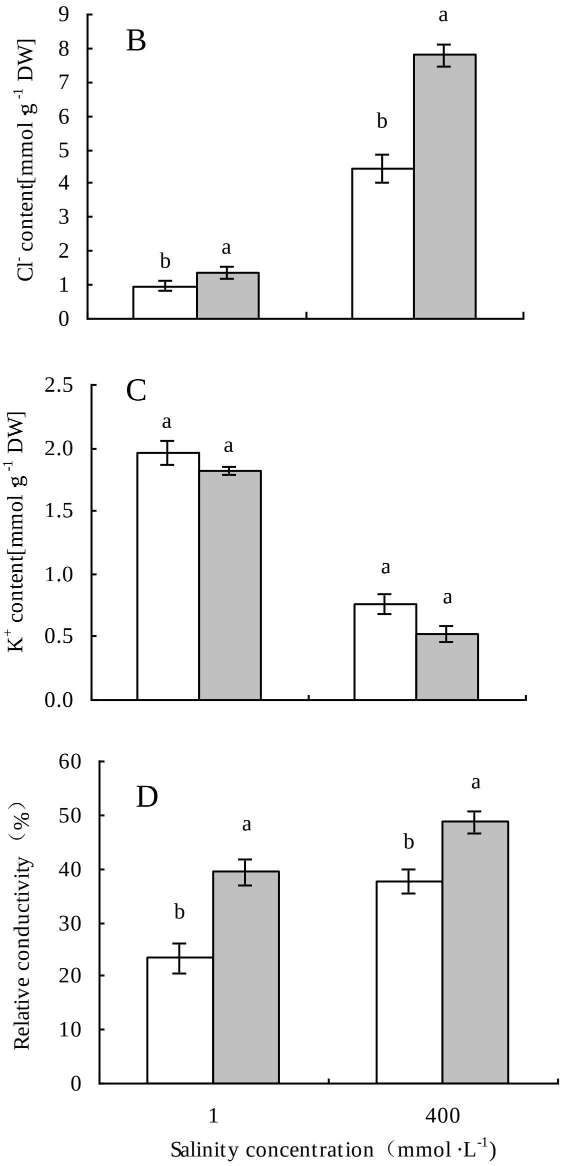


Fig.1 Na^+, K^+, Cl^- concentration and relative conductivity in leaves of *S. physophora* seedlings after combined salinity and drought treatment. Within each NaCl treatment, means with different letters are significantly different at P<0.05. Vertical bars represent standard errors (n=3).

3 RESULTS

3.1 *Effect of combined salinity and drought stress on inorganic ion and relative conductivity in leaves*

The concentration of Na^+ and Cl^- increased under drought stress, especially at 400mmol L^{-1} NaCl (Figure 1 A,B) while drought had no effect on K^+ concentration regardless of NaCl treatment (Figure 1C).

Drought treatment increased the relative conductivity of leaves at both concentrations of NaCl, especially at 1 mmol L^{-1} NaCl. The relative conductivity of leaves with the drought treatment was 1.7 and 1.3 times in 1 and 400 mmol L^{-1} NaCl respectively of that in leaves of control (Figure 1D).

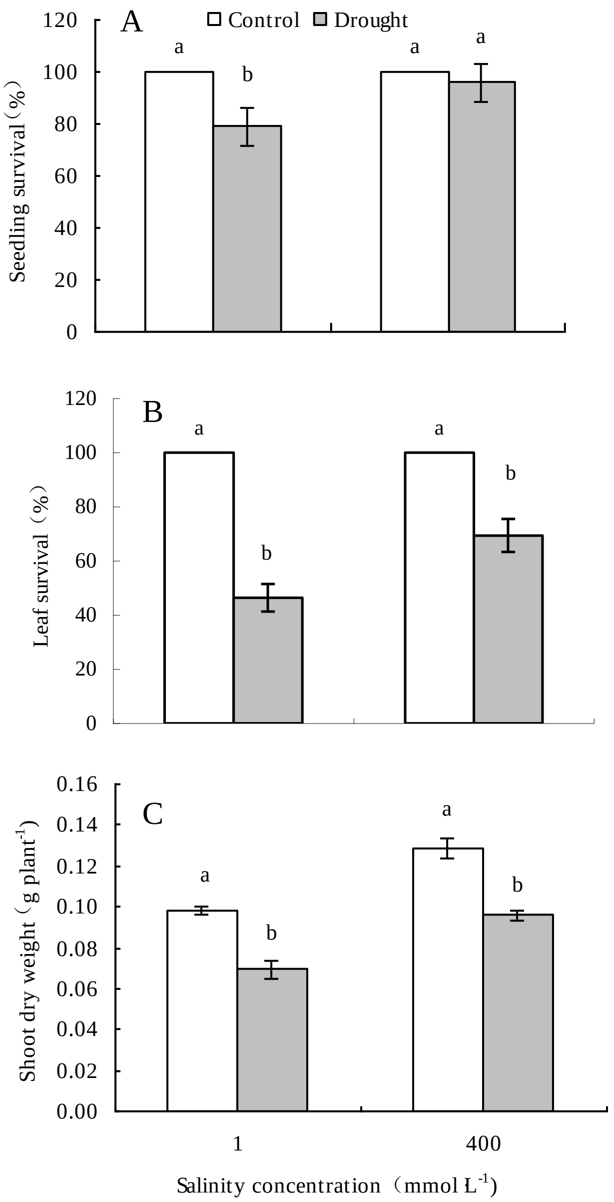


Fig. 2 Seedling and leaf survival and shoot dry weight after *S. physophora* seedlings were rewatered. Within each NaCl treatment, means with different letters are significantly different at P<0.05. Vertical bars represent standard errors (n=3).

3.2 *Effect of combined salinity and drought stress on seedling and leaf survival and shoot dry weight*

Seedling survival pretreated with 1 mmol L^{-1} NaCl was decreased compared to the control, while the value that pretreated with 400 mmol L^{-1} NaCl had no significance difference after seedlings were rewatered (Figure 2A). The similar trend was shown in leaf survival (Figure 2B).

Shoot dry weight decreased at either 1 or 400 mmol L^{-1} NaCl pretreatment after seedlings were rewatered (Figure 2C).

Table 1 Results of two-way *ANOVA* of characteristics of ion content and relative conductivity in leaves of *S. physophora* seedlings after combined salinity and drought treatment; and seedling and leaf survival, and shoot dry weight of *S. physophora* seedlings after seedlings were rewatered (*,** ,*** Denotes significant difference at P < 0.05, P < 0.001 and P < 0.001, respectively, ^{ns} denotes no significant difference. Data represent F values).

Independent variable	Salinity	Drought	Salinity × Drought
Na^+ content	2041.41***	113.24***	103.45***
K^+ content	890.05***	20.84**	1.11 ^{ns}
Cl^- content	755.44***	107.65***	67.13***
Relative conductivity	52.40***	69.11***	2.43 ^{ns}
Shoot dry weight	126.51***	148.62***	0.67 ^{ns}
Seedling survival	11.73*	26.28**	11.73*
Leaf survival	35.67**	478.05***	35.67**

4 DISCUSSION

Gao et al. (2009) found that *S. physophora* has high tolerance to salinity, but the mechanism was not clear. Euhalophytes always accumulate high concentration of inorganic ions to increase the ability of osmotic adjustment (Song et al. 2006a, b). A serious of studies have shown that K^+ was essential to maintain the homeostasis of ions within plant cells (Song et al. 2006a), enzyme activation and protein synthesis (Zhu et al. 1998). Therefore, the stabilization of K^+ under drought stress was important for *S. physophora* seedlings which occurs in saline and arid regions. In addition, Na^+ and Cl^- increased under drought condition. Increased Na^+ and Cl^- may decrease the osmotic potential, which can help plants to absorb water from saline soils. This may be one of the important reasons why *S. physophora* seedlings can survive saline and arid environments.

Both salt and drought stresses can increase the membrane permeability (Lutts et al. 1996). In the present study, drought stress increased the relative conductivity of leaves regardless of the concentration of salinity (1 or 400mmol L^{-1} NaCl). However, under drought condition seedlings pretreated with 400mmol L^{-1} NaCl seemed to have a lighter membrane damage in their leaves than in seedlings pretreated with 1 mmol L^{-1} NaCl. This was consistent with the result that seedlings pretreated with 400 mmol L^{-1} NaCl had a higher seedling and leaf survival percentage than seedlings pretreated with 1 mmol L^{-1} NaCl. Sui et al. (2010) found that the content of unsaturated fatty acids in the euhalophyte *Suaeda salsa* increased by salt stress, and the increase of unsaturated fatty acids in membrane lipids can increase the photosystem tolerance to salt stress. Whether 400 mmol L^{-1} NaCl pretreatment can affect the structure of membranes, and the relationship between the change of membranes structure and the seedling and leaf survival after seedlings were rewatered remains to be further studied.

The present results showed that seedlings of *S. physophora* pretreated with salinity can increase seedling survival, and this can help seedlings to adapt to combined salinity and drought stress in arid areas. This was consistent with the result in *S. salsa* (Huang et al. 2008). More important, seedlings wilted 7 days after drought treatment for 1 mmol L^{-1} NaCl pretreatment, but it was 14 days for 400 mmol L^{-1} NaCl pretreatment. This means seedlings pretreated with 400 mmol L^{-1} NaCl had a higher resistance to drought stress than those pretreated with 1 mmol L^{-1} NaCl. In conclusion, seedlings of *S. physophora* pretreated with salinity can increase seedling survival, and this can help seedlings to adapt to combined salinity and drought stress in arid regions.

5 ACKNOWLEDGMENTS

The financial support from National Natural Science Research Foundation of China (31370420), the Natural Science Research Foundation of Shandong Province (ZR2010CM005), and the Program for Scientific Research Innovation Team in Colleges and Universities of Shandong Province is greatly appreciated.

REFERENCES

[1] Gao, B., Song, J., Liu, J.P., Shi, G.W., Fan, H., Zhao, K.F. & Wang, B.S. 2009. Seedling emergence and salt tolerance of *Suaeda physophora* Pall. under salt stress. *Acta Ecologica Sinic* 29(11): 6131-6135 [in Chinese].

[2] Huang, W., Li, Z.G., Qiao, H.L., Li, C.Z. & Liu, X.J. 2008. Interactive effect of sodium chloride and drought on growth and osmotica of *Suaesa salsa*. *Chinese Journal of Eco-Agriculture* 16(1): 173-178 [in Chinese].

[3] Leul, M. & Zhou, W.J. 1999. Alleviation of waterlogging damage in winter rape by uniconazole application: effects on enzyme activity, lipid peroxidation, and membrane integrity. *Journal of Plant Growth Regulation* 18: 9-14.

[4] Liu, J.P., Gao, B., Li, X., Song, J., Fan, H., Wang, B.S. & Zhao K.F. 2010. The effects of salinity and drought interaction on seed germination and seedling growth of *suaeda salsa* L. from different habitats. *Acta Ecologica Sinica* 30(20): 5485-5490 [in Chinese].

[5] Lutts, S., Kinet, J.M. & Bouharmont, J. 1996. NaCl-induced senescence in leaves of rice (*Oryza sativa* L.) cultivars differing in salinity resistance. *Annals of Botany* 78: 389-398.

[6] Mu, S.Y., Cheng, Z.M., Bao, Q., Yin, L.K. & Pan, H.X. 2006. Analysis on the composition of fatty acids from seed oil of *Suaeda physophora* Pal1.using GC/MS. *Arid Zone Research* 23(3):475-477 [in Chinese].

[7] Song, J., Feng, G., Tian, C.Y. & Zhang, F.S. 2006a. Osmotic adjustment traits of *Suaeda physophora*, *Haloxylon Ammodendron* and *Haloxylon persicum* in field or controlled conditions. *Plant Science* 170: 113-119.

[8] Song, J., Ding, X.D., Feng, G. & Zhang, F.S. 2006b. Nutritional and osmotic roles of nitrate in a euhalophyte and xerophyte in saline conditions. *New Phytologist* 171: 357-366.

[9] Sui, N., Li, M., Li, K. & Wang, B.S. 2010. Increase in unsaturated fatty acids in membrane lipids of *Suaeda salsa* L. enhances protection of PSII under high salinity. *Photosynthetica* 48(4): 623-629.

[10] Wang, L., Tian, C.Y., Zhang, D.Y. & Zhou, Z.B. 2005. Effects of illumination, temperature and salinity on the germination of *Suaeda physophore* Pall. seeds. *Arid Land Geography* 28(5): 670-674 [in Chinese].

[11] Zhu, J.K., Liu, J.P. & Xiong, L.M. 1998. Genetic analysis of salt tolerance in *Arabidopsis*: evidence for a critical role of potassium nutrition. *The Plant Cell* 10: 1181-1191.