Salinity Effects on Germination and Plant Growth of Haloxylon Ammodendron at Qaidam Basin

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Abstract. Haloxylon ammodendron is one of the dominant characterizations of groups in Qaidam Basin. The salinity effects on H. ammodendron was determined by evaluating photosynthetic characteristic and seed germination feature responses in saline conditions in this paper. The reduction of Pn was corresponded to the decreasing Gs in the afternoon, when there was a slight increase in WUE corresponded to Pn and Tr during 15:00 to 17:00p.m in the field trails. There was a delay in Pn and Tr to reach the postmeridian peak under 2% and 3% NaCl, while the daily mean values of WUE under 2% and 3% NaCl were higher than the 0% NaCl control. H. ammodendron seeds were found retaining 72% of germination rate under salinity degree high up to 3.51% saline solution. The values of GP, GE, GI and VI decreased evidently under 0.72% saline solution, whereas the reduction was indistinctive from 0.72% up to 2.14% saline solution without salt injury below 2.14% saline solution. Although the plant showed a slight sensibility to light salinity, H. ammodendron retained a certain potential of seed germination and seedling growth under salinity stress.

Keywords: Qaidam Basin, Haloxylon Ammodendron, Salinity, Photosynthetic Characteristics, Germination

Introduction

Soil salinity is known as an important environmental factor that almost impacts on every stage of plant growth [1]. Researches have shown that the integrity of cell membrane, the activity of various enzymes, the acquisition of nutrients and the function of photosynthetic organs are all vulnerable to be suppressed by the toxic effect of high salt stress [2].

Qaidam Basin in Qinghai Province of China is an inland arid area on the Tibetan Plateau (western China), generally covered by saline soil [3]. There is another environmental issue, which is the wild natural vegetation deterioration caused by the northwest power grid project construction for the further urbanization. Based on the geographic-ecological similarity, one effective approach to improve the fragile ecological environment in Qaidam Basin is to cultivate dominant shrub species with excellent adaptability and positive characteristics under natural environmental condition [4].

Haloxylon ammodendron is one of the dominant plants in Qaidam Basin and has been shown to...
have unique halophytic adaptations that the H. ammodendron roots grow toward optimum soil salinity [5]. It also adapts well to arid desert region with remarkable salt tolerance and it can be a sustainable biofuel feedstock used for multiple shelterbelts, erosion control, soil amelioration, wildlife habitat and mine spoil rehabilitation[6].

Therefore, the main objective of this study was to determine the physiological characteristics of H. ammodendron seed germination and seedling growth dealing with salinity stress. Our results would advance our understanding about the salt-tolerance mechanism of H. ammodendron and help identify the ability of H. ammodendron to cope with the salinity effect in Qaidam Basin.

Materials and Methods

Research Area
The research area is an inland desert with typical plateau continental climate and xerophytia, of which the vegetation mainly consists of H. ammodendron plants. The coverage of the plants ranges from 5% to 8% and the tuft diameter is usually from 50cm to 90cm. The tufts of H. ammodendron plants can be calculated from 6 to 8 with the plants of Nitraria tangutorum and Lycium Chinense associated.

Seedling Pot Experiment
2-year-old seedlings were planted in plastic pots (each per pot) filled with 23 kg native chernozem soil (with the original water content of 24%, pH of 8.1, organic matter content of 19.5 g·kg\(^{-1}\), available P 8.5mg·kg\(^{-1}\), available K 129 mg·kg\(^{-1}\) and total N 78 mg·kg\(^{-1}\)). The plants were maintained for 5 months after transplanting into pots to be prepared for salt treatment exposure. Salt stress treatment was simulated by solutions, which were prepared by dissolving NaCl in water to obtain five salinity levels: 0, 0.6%, 1%, 2%, and 3% NaCl. Each pot of seedling was irrigated with 500 mL of the appropriate salt solution every 5 days, whereas the control (0% NaCl) was irrigated with 500 mL of fresh water. A plastic tray with which we poured the seeping liquor back to the pot was placed under each pot to make sure the appropriate salinity and soil moisture remained stable in each pot. The experiment was performed for 30d under native condition in the open air.

Photosynthetic Characteristics
Measurements of net photosynthetic rate (Pn), stomatal conductance (Gs) and transpiration rate (Tr) were carried out on the fully expanded leaf on middle part of each seedling, with a portable photosynthesis system LI-6400 (LICOR, USA). The measurements were performed every 2 hours from 7:00am to 19:00pm during the daytime at the end of 30d salt stress treatment. The water use efficiency (WUE) of the seedlings was estimated by Pn and Tr according to the following formula:

Germination Assay
Germination tests were conducted in Petri dishes (90 mm) containing two filter papers added 10 mL of treatment solution. Five replications with 20 seeds were used for each of the six salt treatments of 0 (control), 0.72%, 1.43%, 2.14%, 2.83%, and 3.51% solutions of mixed NaCl and Na\(_2\)SO\(_4\). All seeds in the Petri dishes were incubated in a programmed germination chamber (PGX-2000, Binder, China) at a constant temperature of 25\(^{\circ}\)C with 8h natural light condition. The seeds were washed frequently by small amounts of appropriate solutions to maintain the salt concentration.

Germinated seeds were counted and radical length was measured daily for 10d. A seed was recorded as germinated when the seed coat was broken and the radical emerged. The seed germination parameters were calculated with following formulas:

\[
\text{Germinated seeds} = n_1 \times n_2 \times \ldots \times n_{10}
\]

\[
\text{Radical length} = \text{length of radical}
\]

Results

Seedlings under Salt Stress
There was an evident decrease in leaf net photosynthetic rate (Pn) with the increase of salinity after 30d under salt stress. The diurnal variation of Pn showed a bimodal curve (Figure 1A), with the first peak showed at 11:00a.m and an obvious decrease at 13:00p.m. The result showed that in each trail with NaCl treatment of 0%(control), 0.6%, 1%, 2% and 3%, the valley value compared to the antemeridian peak decreased by 36.3%, 42.5%, 37.3%, 47.5% and 51.7%, respectively. The Pn with the treatment of 0%, 0.6% and 1% NaCl reached the second peak at 15:00p.m, however in 2% and 3% NaCl were 2 hours delayed. The Gs values of 2% and 3% NaCl treatment reached the second peak at the same time with the other three groups of trails, and the postmeridian peak value was lower than the antemeridian one in each trail. After 30d of 0.6%, 1%, 2% and 3% NaCl treatment, the result of the Gs value at 11:00a.m showed an evident decrease by 19.8%, 30.2%, 51.9% and 76.3%, respectively (Figure 1B). The diurnal variation of Tr in the leaves of plants showed a similar trend with Pn under each treatment (Figure 1C). However, the value of water use efficiency in leaves of plants (WUE) with the increasing salinity treatment showed a different trend without any regular reduction (Figure 1D). The values of WUE in trails of control, 1% NaCl and 2% NaCl reached the first peak of 2.91, 2.88 and 2.92 μmolCO₂·mmol⁻¹H₂O, respectively at 11:00a.m, while The values of WUE in trails of 0.6% NaCl and 3% NaCl reached the first peak of 2.76 and 2.87μmolCO₂·mmol⁻¹H₂O, respectively at 9:00a.m. The postmeridian peak in trails of control, 1% NaCl and 2% NaCl showed at 17:00p.m was 1.84, 2.81 and 2.74μmolCO₂·mmol⁻¹H₂O, respectively, while it of 0.6% NaCl and 3% NaCl treatment showed at 15:00p.m was 2.59 and 2.85μmolCO₂·mmol⁻¹H₂O, respectively.

Figure1. Diurnal variation in net photosynthetic rate (Pn) (A), stomatal conductance (Gs) (B), transpiration rate (Tr) (C) and water use efficiency (WUE) (D) in the leaves of H. ammodendron subjected to all salinity levels.

Seed Germination
Figure 2. Changes over time in germination percentage of H. mmodendron seed at different concentration of saline solution. (N=5)

Figure 3. Mean germination time at different concentration of saline solution for H. ammodendron. (N=5)

Figure 4. Germination energy (A), germination index (B), vigor index (C) and relative salt harm rate (D) at different concentration of saline solution for H. ammodendron. (N=5)

The germination rate (GP) was not affected by salt concentrations up to 1.43% and decreased from 1.43% to 3.51% saline solution. However, it remained a relatively high germination rate (>85%) under
2.14% to 2.83% saline solution without significant difference (F=2.76, P=0.98>0.05). The final germination percentage was 99.6%, 89.6%, and 72% of the treatment at 2.14%, 2.83%, and 3.51% saline solution, respectively (Figure 2).

The mean germination time was evidently extended with the increase of salinity (Figure 3). There was a sharp reduction showed in mean germination speed (MGS) at 71.95% under the treatment of 0.72% saline solution, and the mean germination speed under treatment of control, 0.72%, 1.43%, 2.14%, 2.83% and 3.51% saline solution was 2.1, 3.61, 3.72, 4.36, 4.56 and 5.25d, respectively.

The result showed that the germination energy (GE) decreased with the increasing salinity (Figure 4A). The GE value of 65% at 0.72% saline solution decreased by 35% than it in control group, however GE at 1.43% saline solution was 63%, showing no evident decrease with it in 0.72% saline solution. The value of GE at 2.14%, 2.83% and 3.51% saline solution was 50%, 43% and 27%, respectively. The value of vigor index (VI) showed a similar trend with GE (Figure 4C) and the declines of VI also resulted in the corresponding reduction in germination index (GI) (Figure 4B). There was no evident inhibition in *H. ammodendron* germination under low salinity treatments (salt concentration below 2.14%), while from 2.83% to 3.51% saline solution the value of relative salt harm rate (RSHR) increased to 11% and 28%, respectively.

**Table 1.** Equations of regression models of seed germination percentage (GP) at different concentration of saline solution for *H. ammodendron*

| Regression model | Equation of regression models | $R^2$  | $P$     |
|------------------|-------------------------------|--------|---------|
| Linear regression | $-6.925x+105.802$             | 0.804  | 0.054c  |
| Quadratic regression | $-4.683x^2+9.517x+98.112$    | 0.977  | 0.015   |
| Cubic regression | $-1.866x^3+5.141x^2-3.081x+100.0$ | 0.999b | 0.004   |

a In the equations, percentage germination is the dependent variable (y), concentration of saline solution is the independent variable (x);
b Indicated the model fitness of this model was evaluated as the best

![Figure 5](image.png)

**Figure 5.** Three regression models of seed germination percentage (GP) at different concentration of saline solution for *H. ammodendron*

The two curvilinear models were statistically significant (P<0.05) in the regression analysis, while
the linear regression model was not (P>0.05). Based on this statistical significance, the determining coefficient $R^2$ of quadratic regression equation was 0.977, and the $R^2$ of cubic regression equation was 0.999 (Table.1). The cubic regression model was found to be better than the quadratic regression model in goodness of fit.

**Discussion**

An exposure to hyposaline or hypersaline conditions inhibited the photosynthesis of *H. ammodendron* as compared to control salinity condition, and yet the Pn at all levels of salt stress showed no sharp reduction from antemeridian peak to valley value in the noon affected by the mid-depression. Besides, there was a less decline at noon in Pn of seedlings with 1%NaCl than it with 0.6%NaCl. This indicated a salt tolerance adaption to light and heat for *H. ammodendron*.

There was a stronger inhibition in transpiration than in photosynthesis of *H. ammodendron* seedlings under 0.6% NaCl treatment, and the greater reduction of Pn resulted in the decline of water use efficiency. As the salinity increased, however, there was a lower Tr than Pn showing up enhanced the water use efficiency. Moreover, the daily mean values of WUE in leaves of seedlings under 2% and 3% NaCl treatment was higher than it of control salinity treatment, indicating a water use efficiency improvement in *H. ammodendron* under salt stress.

The germination capacity of *H. ammodendron* under salt stress varies with different provenances [7, 8]. It is further illustrated that the seed germination characteristics response to salt stress and its distribution of natural habitats are highly relevant, especially in unpredictable desert areas where the seed germination processes associated with the response may develop in the changing environment. *H.ammodendron* in Qaidam Basin exhibited high tolerance to salinity, specifically under the salt concentrations between 0.72% and 2.14%. *H. ammodendron* retained 46% of its germination index under high salt stress levels up to 3.51% saline solution. Similar results have been reported for other perennial halophytic shrubs [9].

Correlation and regression analysis have been commonly used to reveal the association between two continuous variables in the ecological research of germination [10-12]. Our study showed that the linear regression model of the relationship between seed germination rate of *H. ammodendron* and salinity presented a negative goodness of fit, therefore, it failed to highlight that there was no significant germination difference between moderate salinity conditions and light salinity conditions (Figure.5). Though it demanded further research and more trials for verification and complement, the goodness of fit in cubic regression model of correlation between germination and salinity was positive.

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