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Research Article

Screening for Salt Tolerance in Eight Halophyte Species from Yellow River Delta at the Two Initial Growth Stages

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Screening of available local halophytes for salinity tolerance is of considerable economic value for the utilization of heavy salt-affected lands in coastal tidal-flat areas and other saline areas. In this study, the germination and seedling pot experiments on salt tolerance of eight halophytic species from Yellow River Delta, China, at seven NaCl concentrations (0, 50, 100, 150, 200, 250, and 300 mM), were conducted at both growth stages. Results showed that germination rate and germination index decreased with an increase in NaCl concentration. The higher germination rates were obtained from *Tamarix chinensis* and *Suaeda salsa* seeds exposed to 0~200 mM NaCl. At the seedling stage, the salt tolerances of eight halophytes were also different from each other. *Tamarix chinensis* had significantly greater fresh biomass and plant height in relative terms than the others in all salt treatments. The order of the relative growth yield in seedling was *Tamarix chinensis* > *Suaeda salsa* > *Salicornia europaea* > *Limonium bicolor* > *Atriplex isatidea* > *Apocynum venetum* > *Phragmites australis* > *Sesbania cannabina*. The comprehensive analysis showed that *Tamarix chinensis* had the highest tolerance to salt, followed by *Suaeda salsa*, and the salt tolerance of *Sesbania cannabina* was the lowest.

1. Introduction

Soil salinization is one of the most serious impediments to agricultural production both in China and the other regions of the world [1, 2]. According to statistics, there is about 9.54×10^8 hm^2 of saline soil worldwide, and seven percent of the land surface and five percent of cultivated lands are affected by salinity [3, 4]. China has all kinds of saline soils with a total area of about 0.99×10^8 hm^2. In the Yellow River Delta alone, there is approximately 44.3×10^4 hm^2 of seashore salinized tidal flat, including heavily salinized soil (soil salinity is over 0.6%) and saline-alkaline bare land with an area of 23.63×10^4 hm^2. And this number continues to grow at a rate of 2.2×10^4 hm^2 per year due to a variety of natural and human activities [5–7]. On these saline lands, it is not suitable for growth of traditional crops because of extreme salinity and other adverse factors. If plant salt tolerance cannot be improved, then vast amounts of soils may be left uncultivated. This will severely threaten the national food security and biomass energy production.

In recent years the development thinking of solonchak agriculture is brought up at home and abroad. Namely, salinized soils can be utilized through the transgenic technology or the breeding of salt-tolerant plants, which may successfully maintain a relatively reasonable yield and an increased growth on salt-affected soils. And then some approaches to overcome the salinity problem have been put forward by various plant scientists [1, 2, 8]. For example, large scale soil was ameliorated to meet the needs of plant growth by either altering farming practices to prevent soil salinization or implementing schemes to remediate salinized soils. One of the most feasible and economic paths, which is of prime importance, is the screening of available local halophytes for salinity tolerance, despite its limitation of time required and environment dependence.

Halophytes are plants, which are able to grow or survive in saline conditions and have considerable importance as food, forage, and material source for biofuel [9]. Cultivation of halophytes or salt-tolerant plants on the salt soil in some cases would spare arable land and fresh water for conventional agriculture. Despite strong adaptations to saline environments, halophytes are sensitive to salt stress, like many other traditional crops, and may not sustain good growth or yield when they are grown in soils with high salt concentrations [10, 11]. In recent years, extensive research on plant screening for salt tolerance has been conducted, with the aim of providing a relatively tolerant cultivar, but these researches mainly focused on conventional crops, screening criteria, and methods for plants salt tolerance [1, 12–15]. Unfortunately, there are few investigations about the screening of available halophyte species and their responses to heavy saline conditions.

Keeping this in mind, the work presented here was carried out to examine the salinity tolerance of eight local halophytes by germination and pot experiments when exposed to different NaCl concentrations. The aim of this study was to determine how far the ecological amplitude, in relation to salt, of a range of halophyte species may be restricted by their inability to evolve salt tolerance and finally screen the most adaptive salt-tolerant halophytes which can grow well on the heavy salt soils.

2. Materials and Methods

The 8 halophyte species *(Tamarix chinensis, Suaeda salsa, Atriplex isatidea, Apocynum venetum, Sesbania cannabina, Salicornia europaea, Phragmites australis, and Limonium bicolor)* were used in this study. The seed material was collected during October 2010 from Halophytes Garden of Dongying in the Yellow River Delta, China, and stored for four months at room temperature (22°C) and 50% relative humidity. Prior to experimentation, seed samples were surface sterilized using 5% sodium hypochlorite solution for five minutes and thoroughly rinsed with distilled water.

2.1. Germination Experiment. The germination experiment was conducted in a growth chamber at $26 \pm 2^{\circ}$C, with 12 h day length, at a light intensity of 36 Wm^{-2} and relative humidity of 76%. 30 surface sterilized seeds of each halophyte were placed on moistened filter paper in a 9 cm plastic Petri dish. The plastic Petri dishes were arranged in a completely randomized design, with five replicates, seven salt treatments (0, 50, 100, 150, 200, 250, and 300 mM NaCl), and the 8 halophyte species mentioned above. 5 mL of appropriate treatment solution was applied on alternate days to each Petri dish after rinsing out the previous solution. A seed was considered to have germinated when both plumule and radicle had emerged ≥2 mm. The number of germinated seeds was counted daily for 7 days. The rate of germination was expressed a percentage of the number of germination seeds divided by the number of tested seeds for each treatment. The germination index (GI) was estimated using a modified Timson index [16] of germination velocity, $\mathrm{GI} = \sum G/t$ (where G is the number of seed germination every day, and t is the corresponding number of days for germination test). The relative germination index (RGI) is expressed as a ratio of germination index under salt stress to germination index in control treatment.

2.2. Seedling Experiment. Seedling Experiments for salt tolerance were conducted to evaluate the effects of salinity on halophyte growth in a glasshouse at $24 \pm 3^{\circ}$C day temperature and $12 \pm 1^{\circ}$C night temperature. For each halophyte, twenty to thirty seeds, depending upon 8 halophytic species, were sown in a 3 L PVC (polyvinyl chloride) pot with a mixture containing 70% perlite and 30% dry sand. After two weeks, seedlings were thinned to leave seven uniform and healthy seedlings in each pot. All the pots were irrigated for one week with Hoagland solution every alternate day. The concentrations of NaCl used were exactly the same as we used in the germination experiment, namely, 0, 50, 100, 150, 200, 250, and 300 mM. The experiment was laid out in a completely randomized design with five replications in each treatment. NaCl treatment was applied to 3-week-old plants and lasted for 5 weeks. The salt concentration was increased in aliquots of 25 mM on alternate days until the appropriate salt treatment was reached. Plants were watered twice a day with about 50 mL solution applied each time per pot. The symptoms of plant injury at salt stress were observed at any time during the course of the experiment. After 35 days of NaCl treatment, two measurements were undertaken in each treatment for both plant height and fresh weight of aboveground biomass. Salt tolerance of plant has been assessed by measuring the relative growth rate and the salt damage rate, which were expressed as follows:

$$\text{relative growth rate} = \frac{\text{plant growth at salt concentration}}{\text{plant growth at control treatment}} \times 100\%,$$
$$\text{salt-injury rate} = \frac{\text{number of plants with salt-injury symptoms}}{\text{total number of plants}} \times 100\%. \quad (1)$$

2.3. Statistical Analysis. Data were analyzed statistically using a one-way analysis of variance (ANOVA), linear regression, and correlation analysis, and the means of each treatment were analyzed by Duncan's multiple range test. All statistical methods were performed with SAS software [17].

3. Results

3.1. Effect of Different Concentrations of NaCl on the Seed Germination. One-way ANOVA of the data for germination rate of the 8 halophyte seeds indicated that salt treatment

Table 1: Results of one-way ANOVA for germination rate of the eight species at different NaCl treatments.

Species	df	Mean square	F	P
Sesbania cannabina	6	16.63	21.48	<0.01
Limonium bicolor	6	19.32	20.04	<0.01
Suaeda salsa	6	31.32	27.08	<0.01
Tamarix chinensis	6	38.14	19.16	<0.01
Apocynum venetum	6	21.54	14.28	<0.01
Salicornia europaea	6	14.45	33.87	<0.01
Phragmites australis	6	15.76	18.93	<0.01
Atriplex isatidea	6	41.46	30.37	<0.01

Table 2: Results of one-way ANOVA for germination index of the eight species at different NaCl treatments.

Species	df	Mean square	F-value	P value
S. cannabina	6	15.78	41.25	<0.001
L. bicolor	6	13.32	84.16	<0.001
S. salsa	6	16.89	89.56	<0.001
T. chinensis	6	18.34	59.51	<0.001
A. venetum	6	17.52	71.30	<0.001
S. europaea	6	16.95	46.27	<0.001
P. australis	6	14.35	21.31	<0.001
A. isatidea	6	11.64	12.33	<0.05

had a significantly adverse effect on total germination rate (Table 1). As the NaCl concentration increased, the eight species all exhibited a decreasing trend of germination rate (Figure 1). For example, compared with the control, the total germination rates of *Suaeda salsa* at 50, 100, 150, 200, 250, and 300 mM NaCl treatments were 94.5%, 87.2%, 81.4%, 78.4%, 69.3%, and 56.2% of the control, respectively. Although the germination of halophyte seeds was strongly inhibited when they were subjected to salt stress, the degree of inhibition differed markedly. The eight halophytic species tested in this study could be classified into three groups depending on their ability to germinate in saline medium. First group was the most salt tolerant and had the smallest degree of salt inhibition. These plants (*Suaeda salsa*, *Tamarix chinensis*, *Apocynum venetum*, and *Salicornia europaea*) in this group had higher final germination rate (>80%) when the salinity was less than 100 mM NaCl and still had more than 40% of the germination rate even on the highest salinity condition (300 mM NaCl) (Figures 1(c)~1(d)). The second was the moderate tolerant halophytes, including *Sesbania cannabina* and *Limonium bicolor*. Their seeds also retained high germination rate at low saline (≤50 mM NaCl) and nonsalt treatments, whereas the germination rate decreased significantly at 150 mM NaCl (Figures 1(a) and 1(b)). The third was the least tolerant at the germination stage. The halophytes, *Phragmites australis* and *Atriplex isatidea*, each had the lowest germination rate as compared to the other six halophytes even if the NaCl concentration was very low, or under the without salinity conditions (Figures 1(g) and 1(h)). This may be related to the lower viability of the two species.

Variance analysis of the data for GI also showed that salt treatment had a significant effect on germination of the eight species (Table 2). The GI had the same change trend with that of germination rate. As the salt concentration increased, the GI of the eight halophyte seeds gradually decreased (Table 3). In the eight species *Tamarix chinensis* under all NaCl treatments had the highest GI, followed by *Suaeda salsa* and *Apocynum venetum*. And when the salinity concentration was less than 150 mM, the GI of *Tamarix chinensis* was more than 84%. However, the other five halophytes, *Sesbania cannabina*, *Salicornia europaea*, *Phragmites australis*, *Atriplex isatidea*, and *Limonium bicolor*, each showed a very poor GI (lower than 40.0%) both in nonsalt and all salt treatments (Table 3). Among them, the GI of *Phragmites australis* and *Atriplex isatidea* rapidly decreased to 0.1% and 1.7%, respectively, at 250 mM NaCl, and when the concentration of NaCl was over 200 mM, the germination of *Sesbania cannabina* and *Limonium bicolor* was completely inhibited (Table 3). The results indicated that there was tremendous difference in ability of halophytes to germinate in the presence of NaCl salinity.

From Table 4, it could be seen that the relative germination index had a significantly linear negative relationship with NaCl concentration (all $r < -0.9$, all $P \leq 0.01$), which again showed that salt treatment had a significantly adverse effect on germination of halophytic seeds. According to the linear regression equations listed in Table 4 and the method proposed by Bai et al. [18] and Zeng et al. [11], let the relative germination index be equal to 75%, 50%, and 25% respectively; we could obtain the appropriate, critical, and limited values of salt concentration for germination of the eight halophyte seeds under salt stress conditions. Data in Table 4 demonstrated that at the germination stage, *Tamarix chinensis* was the most salt tolerant of all the tested halophyte seeds, which was consistent with the results observed in Figure 1.

3.2. Effect of Different NaCl Treatments on the Growth of Halophytes at the Seedling Stage. Analyses of variance of the data for relative growth for the eight halophytes showed that five weeks of salt treatment had a significant influence on growth characteristics measured (plant height $P \leq 0.01$; above-ground biomass $P \leq 0.01$) at the seedling stage. As the salt concentration increases, the degrees of growth inhibition and salt-injury rate increase. High NaCl treatment (≥200 mM) had an obviously adverse inhibition on all tested halophytes, with the relative growth rate (fresh weight of above-ground biomass and plant height) being fast reduced, and the salt-injury rate increased rapidly as the NaCl concentration increased above 150 mM (Figures 2 and 3). For example, the seedlings of *Sesbania cannabina* and *Phragmites australis* were dying at 300 mM NaCl (Figure 2), and their salt-injury rates were drastically increased from 5.1% (*Sesbania cannabina*) and 4.5% (*Phragmites australis*) at 150 mM NaCl to nearly 100% at 300 mM NaCl (Figure 3), accompanied by death of individual whole plant.

However, when tested plants were under hyposaline, there were some differences in relative growth and salt-injury

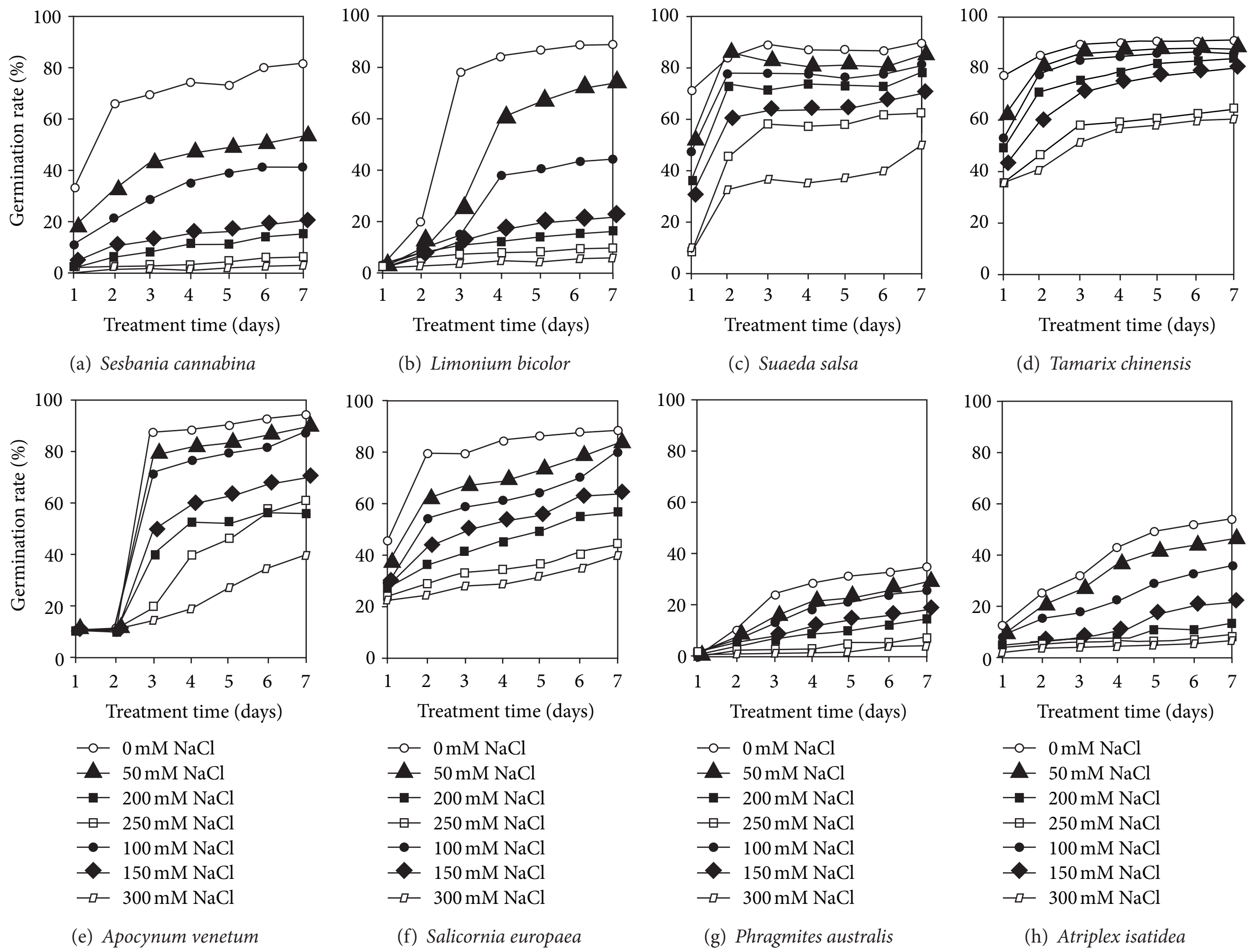


Figure 1: Changes in germination rates with treatment days at different NaCl concentrations.

Table 3: Germination indexes of 8 halophyte seeds at different NaCl concentrations.

Species	Germination index						
	0 mM	50 mM	100 mM	150 mM	200 mM	250 mM	300 mM
S. cannabina	28.7 ± 4.10	13.3 ± 2.71	11.5 ± 2.35	9.6 ± 1.60	7.8 ± 1.64	0.0 ± 0.00	0.0 ± 0.00
L. bicolor	36.4 ± 3.51	32.0 ± 3.68	18.4 ± 3.80	6.7 ± 1.09	1.4 ± 0.12	0.0 ± 0.00	0.0 ± 0.00
S. salsa	89.2 ± 4.25	84.8 ± 4.60	81.6 ± 3.69	77.1 ± 2.94	50.3 ± 4.24	42.4 ± 3.14	21.5 ± 2.65
T. chinensis	98.3 ± 0.87	95.6 ± 1.15	94.1 ± 2.00	84.7 ± 5.31	55.4 ± 7.51	49.4 ± 2.40	36.7 ± 3.78
A. venetum	65.2 ± 1.93	61.7 ± 3.77	59.5 ± 1.71	45.0 ± 5.13	38.5 ± 4.67	33.5 ± 3.07	21.1 ± 4.25
S. europaea	34.0 ± 5.33	28.4 ± 4.15	30.9 ± 4.72	26.8 ± 3.02	25.4 ± 2.34	21.8 ± 4.37	18.8 ± 3.64
P. australis	19.7 ± 4.55	17.9 ± 4.62	13.6 ± 3.68	4.4 ± 3.07	1.5 ± 1.09	0.1 ± 0.21	0.0 ± 0.00
A. isatidea	11.8 ± 2.11	8.1 ± 1.17	9.0 ± 1.82	5.5 ± 1.05	4.2 ± 0.30	1.7 ± 0.34	0.4 ± 0.09

Values are means ± SE ($n = 5$).

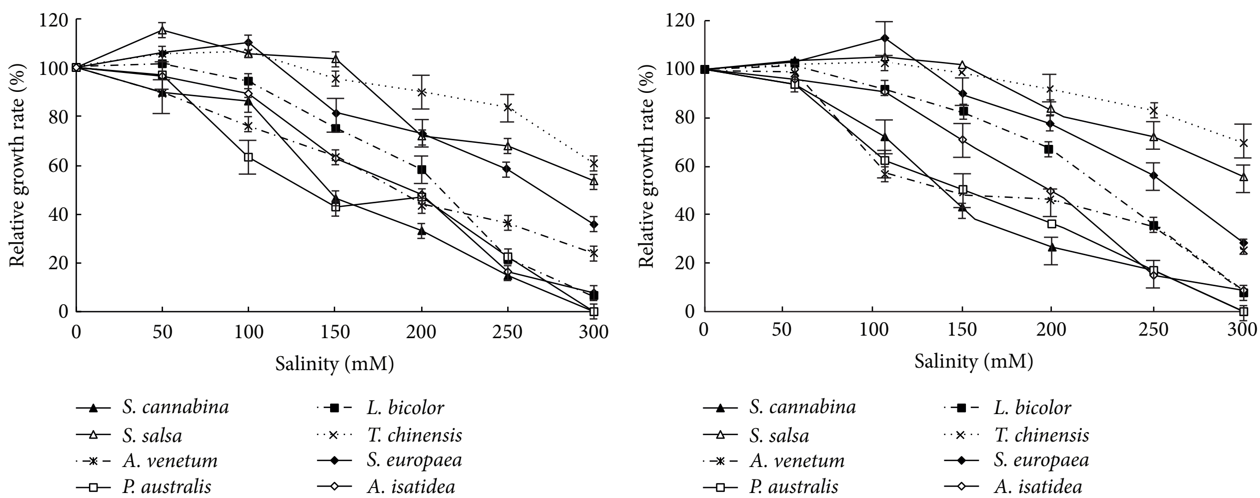
rate for different halophytic species. At 50~100 mM NaCl the relative growth rates of *Tamarix chinensis* and *Salicornia europaea* increased gradually with an increase in salinity and were greater than those of the control plants (Figure 2).

There was also a certain increase in relative growth for *Suaeda salsa* at less than 200 mM NaCl as well as for *Limonium bicolor* exposed to 50 mM NaCl compared with the control treatment, which showed that low salt stress could promote the seedling growth of some halophytes. And within the scope of this treatment, all the halophytes examined in this study did not show apparent symptoms of salt injury for their salt-tolerant ability at the seedling stage, except for the fact that two halophytes, *Sesbania cannabina* and *Phragmites australis*, presented some symptoms of salt

Table 4: Correlation between relative germination index of eight halophyte seeds and salt concentration.

Species	Regression equation	Regression coefficient (R^2)	Correlated coefficient (r)	Salt tolerance (mM NaCl)		
				A	*B*	*C*
S. cannabina	$y = -0.2576x + 78.15$	0.8492	-0.9215^{**}	12.2	109.3	206.3
L. bicolor	$y = -0.2210x + 89.63$	0.8316	-0.9119^{**}	66.2	179.3	292.4
S. salsa	$y = -0.2557x + 109.91$	0.9078	-0.9528^{**}	136.5	234.3	332.1
T. chinensis	$y = -0.2297x + 109.18$	0.9099	-0.9539^{**}	148.8	257.6	366.5
A. venetum	$y = -0.2287x + 104.31$	0.9633	-0.9815^{**}	128.2	237.5	346.8
S. europaea	$y = -0.2349x + 98.52$	0.9141	-0.9561^{**}	100.1	206.6	312.9
P. australis	$y = -0.3875x + 99.48$	0.9107	-0.9543^{**}	63.2	127.7	192.2
A. isatidea	$y = -0.3332x + 97.57$	0.9518	-0.9756^{**}	67.7	142.7	217.8

Note: **denotes significant at ≤0.01 level. In the regression equation, y is relative germination index, and x is salt concentration. *A*: appropriate value of salt concentration for seed germination; *B*: critical value of salt concentration for seed germination; *C*: limited value of salt concentration for seed germination.



(a) Plant height

(b) Above-ground biomass

Figure 2: Relative growth rate of the eight halophytes after 5-week exposure to different salt concentrations. Each point represents the mean value ± SD.

injury (leaf margin scorch, leaf turning yellow, and falling off) and a more growth inhibition in relative terms under 150 mM NaCl treatment (Figure 3). This again indicated that different halophytes responded differently to NaCl treatment.

The above results showed that the salt tolerance of eight halophyte seedlings were different from each other. Among them, *Sesbania cannabina* had the lowest salt tolerance, whose average relative growth rate was just 49.1% with the average salt-injury rate of 41.9%, while *Tamarix chinensis* had the highest salt tolerance as compared to the other seven species in salt treatments, whose average relative growth increment was as high as 91.1%, only accompanied by the average salt-injury rate of 5.7% (Table 5). On the basis of their performance in relative growth and salt-injury rate (Figures 2 and 3, Table 5), in all the tested halophytes, the sequence of salt tolerance from strong to weak was as follows: *Tamarix chinensis*, *Suaeda salsa*, *Salicornia europaea*, *Limonium bicolor*, *Atriplex isatidea*, *Apocynum venetum*, *Phragmites australis*, and *Sesbania cannabina*.

4. Discussion

Screening of available halophytes for salinity tolerance is of considerable value for the economic utilization of salt-affected soils in coastal tidal-flat areas. To explore salt tolerance of 8 halophyte species at the germination and seedling stages was examined in our study. In the germination experiment, salt stress markedly induced lower germination rate and germination index of the eight halophyte seeds (Tables 1~3, Figure 1). For instance, for halophytes *Atriplex isatidea*, *Phragmites australis*, *Sesbania cannabina*, and *Limonium bicolor*, at 300 mM NaCl, only less than 5% seeds germinated, and their germination indexes were also nearly 0% (Table 3). This showed that germination of some halophyte seeds might be completely inhibited under high salt conditions. Similar results were also determined in some species of *Reaumuria trigyna* [19], *Aeluropus lagopoides* [20], and *Salsola vermiculata* [8].

A significant and negative correlation was found between data for relative germination index and NaCl concentration

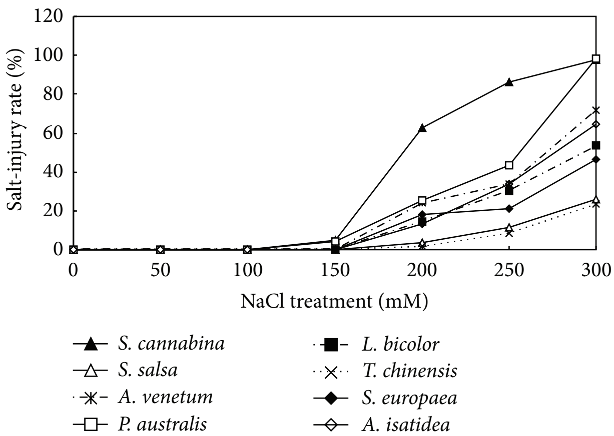


Figure 3: Salt-injury rate (%) of the eight halophytes after 5-week growth in different salt concentrations.

Table 5: Mean salt-injury rate and mean relative growth rate of the eight halophytes after 5-week exposure to different salt concentrations.

Species	Mean salt-injury rate (%)	Mean relative growth rate (%)
S. cannabina	41.9	49.1
L. bicolor	16.3	63.7
S. salsa	6.8	86.4
T. chinensis	5.7	91.1
A. venetum	21.6	52.3
S. europaea	14.3	77.1
P. australis	28.6	51.3
A. isatidea	18.7	54.1

Note: the mean relative growth rate here was above-ground biomass.

(Table 4). The higher the NaCl concentration, the lower the germination index of halophytes (Table 3). The decrease in ability of halophytes to germinate under salinity conditions was probably due to a reversible osmotic effect that induced dormancy by saline stress [21]. The germinability of halophytes at salinity stress was reported by Chen et al. [22], who found that the germination rate of *Apocynum venetum* seeds increased with NaCl concentrations below 150 mM, implicating that low salt stress could promote the seed germination of halophytic species. In this experiment, however, the germination of tested halophyte seeds decreased even if the NaCl concentration was low (Figure 1, Table 3), except for the fact that 50 mM NaCl had a slight promotion to germination of *Suaeda salsa* on the second day of the salt treatment (Figure 1(c)). The reasons for the discrepancy between our result and result reported by Chen et al. [22] could be attributed to two aspects. Firstly, low salt stress might inhibit seed germination of halophytes as well as break the seed dormancy, eventually promoting seed germination. Secondly, Chen et al. [22] only considered germination rate under salinity stress regardless of germination index reflecting both the number of germinated seeds and the speed of seed germination while assessing the salt tolerance at germination. Thus, it was likely to overestimate the salt tolerance of halophyte seeds, as there was an evidence to show that, according to regression equation between seed germination and salt concentration, the appropriate, critical, and ultimate salinity for seeds germination calculated using germination index was less than the corresponding values calculated by relative germination rate [23]. Therefore, although germination rate/relative germination rate has been widely used as an index to determine effects of salt stress on the seed germination, it is not likely that this measurement is appropriate to screen halophytes for salt tolerance.

It has been reported that, regardless of the salt concentration used, salt stress had different degrees of inhibition on the growth of plants [15, 24, 25]. The typical symptom of salinity injury to the plant is the growth retardation, leaf shrink with yellow, and shedding or death, due to the inhibition of cell elongation [26]. In the present study, at the seedling stage, low concentrations of NaCl promoted the seedlings growth of four species, *Tamarix chinensis*, *Suaeda salsa*, *Salicornia europaea*, and *Limonium bicolor* (Figure 2), and the eight halophytes, except for *Sesbania cannabina* and *Phragmites australis*, showed no apparent symptoms of salt injury within 50~150 mM NaCl (Figure 3), indicating no significant effects of low salt stress on the growth of halophytes mentioned above. Similar performances at low salinity were also found in *Puccinellia tenuiflora* [27] and *Atriplex centralasiatica* [28]. For example, Qi et al. [29] and Li et al. [30] found that the growth of *Suaeda salsa* increased significantly with NaCl concentrations when exposed to hyposaline environment (<150 mM NaCl). NaCl solution with high concentration (>150 mM NaCl) caused a reduction in growth and an increase in salt-injury rate of all tested halophytes due to salt stress (Figures 2 and 3). However, the degree of growth inhibition of halophyte species varied at high NaCl concentration. For example, the salt tolerance of *Sesbania cannabina* was the worst in all the tested species, and its individual plant was almost dead after 35 days of 300 mM NaCl treatment. In contrast, *Tamarix chinensis* had the highest salt tolerance; regardless of severity of the salt stress, the relative growth increment remained above 65% (Figure 2) with the average salt-injury rate of 5.7% (Table 5). The inconsistencies existed in salt tolerance among halophytes, which were possibly due to differences in interspecies metabolic rates and sensitivities of different halophytes to salt stress.

Why could low salt stress promote the growth of plant? There were two possible reasons for this. Firstly, halophytes have a nutritional requirement for sodium and an optimal salt concentration during the process of growth (halophyte cannot complete its life cycle for the lack of Na). When the salt concentration in the external solution of plants was less than the optimal salt concentration of halophytes, the increasing of external salinity would probably reduce cell osmotic potential of most halophytes, resulting in the enhancement of water-absorption ability of plant and thereby stimulating the growth of seedlings. Secondly, this may be an adaptation of halophytes to salt stress by accelerating growth in order to reduce the salt concentration [31].

As for the inhibition of high salt stress on growth of halophytes, it could be attributed to decreases in cell metabolism and the toxicity of Na^+ that caused irreversible damage due to prolonged exposure to high concentrations of NaCl [32]. It is generally accepted that, under high salinity conditions, high sodium concentrations in the external solution of plant cells will produce a variety of negative consequences [33]. As only NaCl was used in this study, high salinity might very well lead to ionic imbalance, with excess Na^+ and Cl^- ions having a continual damage on function and structure of cell membrane and leading to membrane dysfunction and cell death [34, 35]. On the other hand, due to the competition for absorptions of Na^+, K^+, Cl^-, and Ca^{2+} to outer membrane, excess Na^+ and Cl^- ions interfered with plants absorption of potassium and calcium and resulted in deficiencies of nutritional elements such as K^+ and Ca^{2+} in plants [36, 37], affecting the growth and development of plants. High salinity also inflicted hyperosmotic shock on plants, as chemical activity of water was decreased, causing a loss of cell turgor. In addition, salt stress generated an increase in reactive oxygen species (ROS), which leaded to decreases in plant photosynthetic capacity [38]. Despite the absence of data of salt stress effects on leaf photochemistry in this study, the fact that NaCl treatment caused a very significant reduction in net CO_2 assimilation, being closely correlated with biomass and plant height, has been proven [39]. Therefore, it appeared that stomatal limitation of photosynthesis was an important factor reducing halophytes growth in saline conditions. Owing to such factors, tested halophytes in this study demonstrated reduced growth at high salinity (Figure 2).

5. Conclusion

Perfectly, results in this study indicated that the eight halophytes had different responses to salt stress at the two initial growth stages. *Tamarix chinensis* and *Suaeda salsa* produced significantly greater above-ground biomass in relative terms and had a higher germination capacity and a lower salt-injury rate than all the other halophytes. Therefore, *Tamarix chinensis* and *Suaeda salsa* were categorized as the most salt tolerant among the eight halophytes appraised. Although the tolerance observed in the present study may or may not be conferred at the adult stage, the performance of seedlings under saline conditions has been considered highly predictive of the response of adult plants to salinity. Thus, the highly salt-tolerant halophytes found in this study would be of considerable economic value for improvement of the heavily saline soils and increasing yield on salt-affected soils in coastal areas. However, the tolerance of halophytes to NaCl single salt only at the germination and seedling stages was investigated in this study. Thus, it is obvious that further field experiment is required to identify exactly the salt tolerance of the eight halophytes at the adult stage.

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