The Influence of Salt Stress on the Accumulation of Na+ and K+ in Tamarix Hispida

Tingting Pan1,a, Weihong Li2,b Yapeng Chen2,c

1 Xinjiang Agricultural University, Urumqi, 830052
2 Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi, 830011

tinggao163@126.com

Abstract

Taking Tamarix hispida as test materials, a group of different concentrations of NaCl were then added to the pots and the salinity was maintained at 3.0(CK), 5.0, 10.0, 15.0 and 20.0g/L. Na+ content and K+ content of different samples were analyzed by ICP-AES. This paper has studied the influence of salt stress on the content and the distribution of Na+ and K+ in Tamarix hispida and discussed the ion transport and selective absorption mechanism of plants under the salt stress. The result shows that Na+ content of Tamarix hispida were increasing prominently with increased salinity and K+ content was rising at first and then decreasing. In the same level of salt concentration, the order of Na+ content and K+ content in Tamarix hispida is leaf > root > stem, leaf is the main part of Na+ accumulation and K+ accumulation. And the stem is just a transmission channel for Na+ where does not exist the cumulative process. In different growth areas, Na+ content is always greater than K+ content. That is because Tamarix hispida is a salt secretion plant. It has expelled the excess salt in leaves outside the body through the salt glands, which will relieve the damage of Na+ on roots to a certain extent. K+/ Na+ in leaves are greater than the one in roots, which explains the salt resistance of leaf is greater than the root.

Keywords: salt stress; Tamarix hispida; Na+; K+

1. Introduction

The soil salinization is a worldwide problem for the mankind, which has become one of the main reasons that damage the crop growth and cause the soil desertification and the ecological environment deterioration. The saline-alkali land in Xinjiang has some characteristics, for example, the area is large, the types are various, the deposited salt is heavy and the formation is complex, etc. The area of various saline-alkali lands is about 11 million km2. The salt composition in north of Xinjiang mostly includes the sulfate or sulfate+chloride. However, the salt composition in south of Xinjiang mostly includes the chloride or chloride+sulfate[1]. The Tamarix hispida is one of the Tamarix L plants that belong to the Tamaticaceae and have the best adversity stress-tolerant abilities. It is the main shrub in desert riparian of Tarim River. It has lots of physical characteristics, such as the drought-resistance, the salinity-resistance...
and so on. Meanwhile, they can also curb the desertification, prevent the wind and fix the sand. Moreover, they can grow in extreme drought areas in which the rainfall is scarce, the evaporation is high and the wind is big. These plants are widely distributed in saline-alkali soils around the Tarim Basin, which has formed the salt shrubs that regard Tamarix hispida as the main species and have had important ecological functions.

For a long time, Tamarix hispida has aroused the attention of scholars depending on its significant ecological and economic benefits as well as the unique ecological and biological characteristics. Nowadays, there have been many reports about the community characteristics of Tamarix hispida, the salt mechanism and the relationship between distribution and salinity[2,3]. And there are also some in-depth studies in the taxonomy of Tamarix hispida[4-6]. This paper has taken the Tamarix hispida as the test materials, mainly focusing on the content and the accumulation of Na+ and K+ in different parts of Tamarix hispida under salt stress as well as its influence. It has analyzed the secretion function of Tamarix hispida, which aims to provide theoretical basis for the repair of desertification as well as the references for restoring and reconstructing the impaired ecosystem along the lower reaches of Tarim River.

2. Materials and Methods

2.1. The design of test.

The test is carried out in the ecology and restoration monitoring test station located in lower reaches of Tarim River. The sandy loam is regarded as the potted medium. On April 2010, the seedlings which grow well and have relatively consistent growth are transplanted to a PVC pipe with a diameter of 30cm and 100cm high. The irrigation water is taken from the underground water in experimental station, in which the ph is 7.25, the salinity is 3.195, the total salt is 3.013 and the Na+ content is 0.605g/L. The water is irrigated every other week. The pot experiment has employed the complete randomized experimental design. And the salt stress is handled in the middle of July. The NaCL is configured into a certain concentration of saline solution and the soil is manured into it once. There are five levels of salt treatment: 3.0g/L(CK), 5.0 g/L, 10.0 g/L, 15.0g/L and 20.0 g/L. It will be irrigated every four days with 5L every time. Six replicates are set per treatment and the samples will be collected every four days. In early August, the leaves of Tamarix hispida under salt irrigation begin to yellow and decline and then the stress processing is ended. There are four times for collecting the samples.

2.2. The experimental method

The Tamarix hispida samples are taken to the lab and washed by tap water in order to remove the surface dirt. At the same time, they need to be washed three times with deionized water. After drying they should be put into the drying oven with a temperature of 60~80℃ for 8~10h. The dried samples are grind the crushed samples are put into the ethylene bottle for use through 200 mesh sieve. 0.5000g (±0.0001) powder samples are weighed and put into the 50ml porcelain crucible. They are firstly carbonized in the furnace with low temperature for 1~2h and then incinerated in muffle furnace for 10~12h (600℃). After incinerating the powder samples, 1:1 nitric acid solution is added into them with 5ml for sample’s dilution and extraction. Then the treated samples are put into 500ml graduated cylinder and the deionized water is used to volume. Moreover, the inductively coupled plasma emission analyzer (ICP-AES) is employed to test Na+ content and K+ content in samples.
2.3. Statistics analysis.

Based on the experimental data, the single factor analysis (ANOVA) has been employed to significantly analyze the differences between different salt stress levels and different growth parts. And the least significant difference (LSD) multiple comparison method has been employed to comparatively describe the differences between different salt stress levels and different growth parts under 95% reliability.

3. Results and Analysis

3.1. The accumulation characteristics of Na+ in Tamarix hispida under salt stress.

The changes of Na+ content in roots, stems and leaves of Tamarix hispida under salt stress with different levels are showed in Figure 1. From this figure, we can find that the Na+ content in leaves of Tamarix hispida is significantly higher than the one in stems. With the strengthening of salt stress, the Na+ content in Tamarix hispida is rapidly increased and the order is leaf > root > stem, which has indicated that the stem is just a transmission channel for Na+ and there is no accumulation process. Therefore, the content in stems is the smallest. The Na+ content in leaves is the highest, when the salt concentration is the highest, the content will be from 13.26 to 14.26. And the Na+ content in roots is from 10.30 to 10.72 while the one in stems is from 9.13 to 9.31. The Na+ content in leaves is significantly higher than the one in roots, which proves that the Tamarix leaves are the main part for accumulating the sodium ions.

The Na+ content in Tamarix hispida leaves have showed significant differences in different levels of salt stress (F5,30=7.92, p<0.001). By NaCL irrigation, the Na+ content in Tamarix hispida leaves has been increased through contrast. When the salt stress is 5, 10g/L, the Na+ content in Tamarix hispida leaves hasn’t showed significant difference. When the salt stress is 15, 20g/L, the Na+ content in Tamarix hispida leaves is significantly higher than the one that the salt stress is 5, 10g/L. However, the Na+ content in leaves hasn’t showed significant difference when the salt stress is 15, 20g/L.

The Na+ content in roots has showed extremely significant differences under different levels of salt stress (F5,30=243.82, p<0.001). Compared with the control group, the different levels of salt stress have all significantly increased the Na+ content in roots. When the salt stress is 10, 15g/L, the Na+ content in roots hasn’t showed extremely significant difference. And when the salt stress is 20g/L, the Na+ content in Tamarix hispida roots is significant higher than the one that the salt stress is 5, 10g/L.

The Na+ content in Tamarix hispida stems has also showed extremely significant differences under different levels of salt stress (F5,30=155.76, p<0.001). After the NaCL irrigation, the Na+ content in Tamarix hispida leaves is higher than the control group. With the strengthening of salt stress, the Na+ content in Tamarix hispida stems has showed a gradually increasing trend.
3.2. The accumulation characteristics of K+ in Tamarix hispida under salt stress.

K+ is one of the essential nutrients in plants, which has played an important role in growth and metabolism of plants. The steady of K+ has close ties with the salt tolerance of plants[7,8]. From the Figure 2, the K+ content in Tamarix hispida leaves is significant higher than the one in roots and stems in the same salt concentration. The K+ content in leaves and stems will be obviously decreased under low salt stress. When the concentration of salt stress is 10g/L, the K+ content in each growth parts has reached the maximum. Then it will be gradually reduced with the increasing of salinity levels. That is because under the higher salt environment, the plants will absorb more K+ so as to reduce the damage of Na+ on plants and be beneficial to the absorption of moisture and nutrients[9]. Therefore, with the gradual increasing of salt, the K+ content in leaves will be increased and it will be reduced only in the environment of higher salt concentration. From the K+ content and the Na+ content, the parts which contain more K+ are also the ones that contain higher Na+. That is the content of K+ and Na+ in leaves is higher than the one in roots and stems.

The K+ content in Tamarix hispida leaves have showed significant differences in different levels of salt stress (F5,30=24.27, \( p < 0.001 \)). After NaCL irrigation, the K+ content in Tamarix hispida leaves is rising at first and then decreasing. When the salt treatment is 5g/L, the K+ content is lower than the control group. That is because the leaves haven’t adapted to the accumulation of K+. When the salt treatment is 10g/L, the K+ content in Tamarix hispida leaves has reached the maximum. And when the salt treatment is 15g/L and 20g/L, the K+ content in Tamarix hispida leaves is significantly lower than the one when the salt treatment is 10g/L.

The K+ content in Tamarix hispida roots have showed significant differences in different levels of salt stress (F5,30=11.71, \( p < 0.001 \)). With the increasing of salt levels, the K+ content in Tamarix hispida roots is rising at first and then decreasing. When the salt treatment is 5g/L, 10g/L and 15g/L, there is no significant difference. Compared with the control group, the K+ content in roots has been obviously increased. When the salt treatment is 20g/L, the K+ content in Tamarix hispida roots is significantly higher than the one when the salt treatment is 10g/L, 10g/L and 15g/L.

The K+ content in Tamarix hispida stems have showed significant differences in different levels of salt stress (F5,30=57.83, \( p < 0.001 \)). After NaCL irrigation, there is no obvious difference of K+ content between Tamarix hispida stems and the control group. With the strengthening of salt treatment, the K+ content in Tamarix hispida stems is rising at first and then decreasing. When the salt treatment is 5g/L, the K+ content is lower than the control group, which is related that the upper land is not as sensitive as the bottom of land for the accumulation of K+.

Fig.2 Effect of salt stress on Tam arix hispida K+ distribution in various organs
3.3. The changes of K⁺ and Na⁺.

The regulation of transportation and distribution of salt in plants is the basic component of salt tolerance mechanism. Generally speaking, the absorption of Na⁺ has accompanied with K⁺ indrawal. And the high affinity K⁺ absorption system also mediates the Na⁺ indrewal. The Tamarix hispida absorbs Na⁺ as well as absorbs an amount of K⁺ under salt stress. And the Na⁺ content is higher than the K⁺ content. The salt stress has reduced the content of K⁺ and Na⁺ in Tamarix hispida to a certain extent. But the ability of absorbing K⁺ in roots has been enhanced with the increasing of salt concentration. Through enhancing the absorption of K⁺, the roots have reduced to absorb Na⁺ in order to maintain the balance of K⁺ and Na⁺ in roots and keep the K⁺ content in a higher level, which can reduce a series of injuries of salt harm on the root system.

From Figure 3, the change trends of K⁺ and Na⁺ in stems and leaves are the same. When the salt treatment is 5g/L, it is reduced. When the salt treatment is from 5g/L to 10g/L, it is rose. And the raise range in leaves is bigger than the one in stems, which proves that under the same salt stress, the leaves’ absorption of K⁺ and its inhibition of Na⁺ are both greater than stems. Later it is reduced which shows that the salt stress has been already above the scope that K⁺ can adjust. It may be related to the secretion of leaves. The change trends of K⁺ and Na⁺ in roots have shown a downward tendency, which shows the salt stress has promoted the transportation of K⁺ to stems and leaves. However, it has inhibited the transportation of Na⁺ to stems and leaves. The content of K⁺ and Na⁺ in roots is always higher than the one in stems and leaves, which proves the sodium tolerance of roots is greater than the one of stems and leaves. But it has increased in high concentration, which shows the performance of absorbing K⁺ hasn’t lost and it still has the ability to resist the salinity damage.

4. Conclusion and Discussion

4.1. The influence of salt stress on the accumulation of Na⁺ in Tamarix hispida

The Na⁺ content in Tamarix hispida leaves is higher than the one in stems and roots under salt stress, which shows the sodium tolerance of Tamarix hispida leaves is greater than the one of roots and stems. The Na⁺ content in roots is higher than the one in stems, that is because the increasing of Na⁺ under salt stress has reduced the penetration potential of roots and also made the roots keep moisture under outside high salt concentration. What’s more, the interception of roots on Na⁺ has limited the transportation of Na⁺ to the upper land, which will keep the photosynthetic organs of leaves from harm and prevent the leaves accumulating more Na⁺ so as to cause ion toxicity. This is the adaptability and the salt-tolerance mechanism of plants on salt stress[10]. When the salt stress is strengthened, the Na⁺ content in roots, stems and leaves will be also increased, which is the same as the conclusion that some researchers think that the Na⁺ content in roots and stems will be increased with the increasing of NaCL concentration[11].

Fig. 3 The change of K⁺/Na⁺ under different salinities
4.2. The influence of salt stress on the accumulation of K+ in Tamarix hispida.

It is necessary to meet the demand of two aspects for the plants that grow in high-concentration salt environment, i.e. the obtainment of mineral elements needed in function metabolism in the process of permeability and growth. In the saline environment, the absorption of K+ is especially important, because the plant must choose to absorb K+ in K+ and Na+ supplied for the plant root cells. The selectivity of this plant’s root system must be sufficient to provide the K+ content that is needed by the plant metabolism in order to keep the K+ content in plants maintain relative stability under higher salt stress. Then it is useful to ensure the K+ content needed by plant growth and function metabolism under salt stress[12]. K+ is the only positive ion existed in relatively high concentration needed by plants[13]. What’s more, keeping the K+ concentration be higher than a specific value in cytoplasm is very necessary to the growth and the salt tolerance of plants. In the environment of higher salt, the plants will absorb more K+ so as to reduce the damage of Na+ on plants, which is beneficial to the absorption of moisture and nutrients. Therefore, with the gradual increasing of salt, the K+ content in plants especially in leaves is gradually increased and it is reduced only in the environment of high concentration. In this experiment, the K+ content in Tamarix hispida leaves and roots is higher than the one in stems, which proves the leaves and the roots are the important places for the accumulation of K+ under salt stress.

4.3. The changes of K+ and Na+ in Tamarix hispida under salt stress.

The salt in soil is ubiquitous. It is a necessary part of soil as well as the nutrition element of plant growth. However, the excessive salt will make the plants cause osmotic stress and interfere the balance of nutrition ions. It will influence the plant metabolism through inhibiting and inducting various enzyme systems. The existing of excessive salt ions in soil will change the nutrient balance of plants through the following two ways: (1) the mutual competition between salt ions and nutrition elements will reduce the absorption of plants on nutrition elements. (2) the salt ions will influence the selectivity of biomembrane on ions and then affect the absorption of roots on nutrition elements. And the salt stress has influenced the absorption, the transportation and the distribution of K+ and Na+ in Tamarix hispida. With the strengthening of salt stress, the Na+ content in Tamarix hispida is rapidly increasing. And at present, no research shows that there is a Na+ transport aiotn in plants. Because K+ and Na+ have the similar ionic radius and hydration energy, both of them will compete the same position of transporter, so Na+ often use the K+ approach into the plants. Recent studies have shown that there are also some ways for Na+ into the plants and the non-selective positive ion channel may be the main way. The competition between K+ and Na+ has caused the wane of K+ in plants. It is also reflected in Tamarix hispida and the content in different places will be reduced with the increasing of salt concentration.

The effective distribution and accumulation of salt ions in plants are the important mechanism for plants to improve its salt tolerance ability. In this experiment, the K+ and Na+ in Tamarix hispida leaves are always higher than the ones in roots. This is possibly related that the Tamarix hispida is a secretion plant. As its salt glands are mainly distributed in the scale leaves, the salt absorbed by leaves is secreted into the leaf surfaces through the salt glands so as to expel the excessive salt ions outside the body, which will relieve the damage of Na+ on roots to a certain extent and reduce the damage of salt on the whole plant.

To sum up, in the same salt concentration levels, the content of K+ and Na+ in Tamarix hispida leaves is higher than the one in stems and roots and the leaves are the main part of accumulating K+ and Na+. The Na+ content will be rapidly increasing with the improvement of salt. The accumulation of Na+ under salt stress has inhibited the absorption of K+. The content of K+ and Na+ in leaves is higher than the one in roots, which shows that the sodium tolerance of leaves is greater than the one of roots.
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