The effect of salt stress on the growth of 3 species of *Nitraria* seedlings

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**Abstract.** In order to compare the salt tolerance of the three species of Nitraria, NaCl with different concentrations was used to stress the Nitraria seedlings. The results showed that salt treatment had different effects on the growth of Nitraria; The inhibiting effect of salt stress on the growth of plant height was in the order of Nitraria tangutorum Bobr>Nitraria roborowskii Kom>Nitraria sibirica Pall; Salt stress caused a rapid decrease in the number of leaves of Nitraria tangutorum Bobr and the number of leaves of Nitraria sibirica Pal rapidly decreased when the salt concentration was greater than 6%, while the relative number of leaves of Nitraria roborowskii Kom significantly decreased when the salt concentration was 15%; With the increase of salt concentration, the order of relative reduction of stem diameter was Nitraria tangutorum Bobr>Nitraria roborowskii Kom>Nitraria sibirica Pall; With the increase of salt concentration, the relative leaf area decreased significantly in the order of Nitraria tangutorum Bobr>Nitraria roborowskii Pall>Nitraria sibirica Kom; With the increase of salt concentration, there was no significant difference between the dry weight and fresh weight of Nitraria roborowskii Kom, but there were significant changes between Nitraria tangutorum Bobr and Nitraria sibirica Pal. According to the comprehensive membership function analysis, the salt tolerance of Nitraria roborowskii Kom was the best, followed by that of Nitraria sibirica Pal, and that of Nitraria tangutorum Bobr was the worst.

1. **Introduction**

*Nitraria* was a xerophyte or super-xerophyte shrub or small shrub of the Zygophyllaceae, which was of great significance to improve and restore the ecological environment. *Nitraria* had strong adaptability and salt-alkali resistance, drought resistance, barren resistance, cold resistance, high temperature resistance, sand resistance and other characteristics [1], which was an excellent plant for improving saline-alkali land and preventing wind and sand fixation [2]. However, there were significant differences in resistance and reproduction characteristics between the *Nitraria* species [3-6]. In order to study the salt-tolerance characteristics of three species of *Nitraria*, the growth indexes of *Nitraria sibirica* Pall, *Nitraria roborowskii* Kom and *Nitraria tangutorum* Bobr under NaCl stress at different concentrations were analyzed to provide a basis for the better application of *Nitraria* in saline-alkali and even heavy saline-alkali lands [7-10].
2. Materials and methods

The tested materials were Nitraria sibirica Palli and Nitraria tangutorum Bobr seeds purchased from Gansu Mingjin Linquan Ecological seed Co., Ltd., and Nitraria roborowskii Kom seeds purchased from Ningxia Yuansheng Green Yang Grass Co., Ltd. (Yinchuan). The seeds stored in the sand for 3 months were washed with clean water and seeded on the vermiculite seedbed. After 2 true leaves were grown, the seeds were transferred into a 10x10 flowerpot with 9 plants in each pot. Three weeks later, the seedlings were stressed with saline of the corresponding concentration. Each pot was 80 mL and NaCl solution was used for salt stress. The treatment concentrations were 0 (control), 3%, 6%, 9%, 12% and 15%, and each was treated with 6 repetitions. After salt treatment for 4 weeks, plant height, leaf number, stem diameter, leaf area, fresh weight and dry weight of the plants were measured respectively. The membership function method was used to calculate the relative plant height, relative leaf number, relative stem diameter, relative leaf area, fresh weight and dry weight of the plant, and root to crown ratio. The salt tolerance of the three kinds of white thorn was compared through comprehensive analysis of various growth indexes [11-14].

3. Results and analysis

3.1. Effects of NaCl stress on 3 kinds of Nitraria plant height

The increase of relative plant height was the ratio of the height of plant increase at the end of salt stress treatment to that at the beginning of stress treatment. As could be seen from figure 1, the increase of relative plant height of 3 species of Nitraria showed a decreasing trend with the increase of NaCl concentration. Nitraria tangutorum Bobr relative height increment was significantly; The change of Nitraria roborowskii Kom was not significant when the NaCl concentration was 0-6%, but it was significant when the NaCl concentration was 9%; The change of Nitraria sibirica Pall was significant when the NaCl concentration was 0-9%, and it was not significant when the NaCl concentration was 12-15%. Compared with the control group, the three kinds of Nitraria decreased by 62.5% to 94.6% at most, with the least decrease in the number of Nitraria roborowskii Kom and the most decrease in the number of Nitraria tangutorum Bobr. The results indicated that NaCl stress had the greatest inhibitory effect on the growth of Nitraria tangutorum Bobr plant height.

![Figure 1. NaCl stress of 3 kinds of Nitraria relative height increment.](image-url)
3.2. Effects of NaCl stress on 3 kinds of Nitraria leaf number
As could be seen from figure 2, the relative number of leaves of 3 species of Nitraria decreased after NaCl stress. The results showed that the leaf growth of Nitraria tangutorum Bobr was faster than that of Nitraria roborowskii Kom and Nitraria sibirica Pall under no-salt stress or low-concentration salt stress, and the leaf growth was significantly inhibited under high-concentration salt stress (> 6%); Nitraria roborowskii Kom was similar to Nitraria tangutorum Bobr, but the turning point was 9%. Although Nitraria sibirica Pall growth general under low concentration of salt, but high concentration of salt can be better growth, only at 15% of the salt concentration, growth will be significantly inhibited. As a result, the Nitraria sibirica Pall from its leaf growth, then the Nitraria tangutorum Bobr and the Nitraria roborowskii Kom more tolerant of salt.

Figure 2. NaCl stress on 3 kinds of Nitraria seedling relative leaf number.

Figure 3. NaCl stress of 3 kinds of Nitraria seedling relative stem diameter increment.
3.3. Effects of NaCl stress on 3 kinds of Nitraria stem diameter
As could be seen from figure 3, the relative increase of stem diameter of Nitraria tangutorum Bobr and Nitraria sibirica Pall showed a decreasing trend with the increase of NaCl stress concentration, while there was no significant change in Nitraria roborowskii Kom. NaCl stress had a certain inhibitory effect on both Nitraria tangutorum Bobr and Nitraria sibirica Pall. Nitraria tangutorum Bobr was more sensitive to NaCl stress, and 3% NaCl concentration would be significantly reduced, while Nitraria sibirica Pall's sensitive concentration to salt was 12%, and the salt concentration had no significant effect on Nitraria roborowskii Kom. This indicated that the salt-tolerant concentration of Nitraria sibirica Pall was significantly higher than that of Nitraria tangutorum Bobr in terms of the relative increase of stem diameter.

3.4. NaCl stress on the influence of 3 kinds of Nitraria relative leaf area
As could be seen from figure 4, the relative leaf area of the three kinds of Nitraria seedlings decreased with the increase of NaCl stress concentration. With low NaCl concentration, Nitraria tangutorum Bobr did not change much, but decreased significantly with the increase of NaCl concentration. The relative leaf area of Nitraria roborowskii Kom increased significantly with 6% NaCl, but decreased rapidly with 9% NaCl and reached 0 with 15% NaCl. Nitraria sibirica Pall was no significant difference in NaCl between 0 and 9%, but NaCl decreased significantly in both 12% and 15%, 41.3 to 78.2% lower than the control group. This indicated that the leaf area of Nitraria tangutorum Bobr was sensitive to 6% NaCl, Nitraria roborowskii Kom was 9% NaCl and Nitraria sibirica Pall was 12% NaCl, so the salt-tolerance of Nitraria sibirica Pall was better than that of Nitraria tangutorum Bobr and Nitraria roborowskii Kom.

![Figure 4. NaCl stress on 3 kinds of Nitraria seedling relative leaf area.](image)

3.5. NaCl stress on 3 species of Nitraria plant fresh weight dry weight and root shoot ratio
As could be seen from figure 5, the fresh weight of Nitraria tangutorum Bobr decreased with the increase of NaCl stress concentration, while the fresh weight of Nitraria roborowskii Kom and Nitraria sibirica Pall first increased and then decreased. Under the stress of 0-6% NaCl, there was little change in Nitraria tangutorum Bobr and Nitraria roborowskii Kom, but significant increase in Nitraria sibirica Pall. Under the concentration of 3% NaCl, the above ground fresh weight of Nitraria sibirica Pall increased to the maximum, 1.4 times of that of the control group. When NaCl stress was
higher than 6%, the above ground fresh weight of *Nitraria tangutorum* Bobr and *Nitraria roborowskii* Kom decreased rapidly, and reached the lowest level when NaCl reached 12%, which was 30.0% and 25.0% of the control group respectively. Although *Nitraria sibirica* Pall decreased, there was no significant difference from the control group. NaCl stress had the least effect on *Nitraria sibirica* Pall, and low concentration promoted the increase of fresh weight.

As could be seen from figure 6, with the increase of NaCl stress concentration, the aboveground dry weight of *Nitraria tangutorum* Bobr and *Nitraria roborowskii* Kom decreased, while the aboveground dry weight of *Nitraria sibirica* Pall fluctuated up and down, but did not increase or
decrease significantly. Under the concentration of 0-6% NaCl, the above ground dry weight of the three species showed little change. With more than 6% NaCl concentration, the above-ground dry weight of *Nitraria tangutorum* Bobr and *Nitraria roborowskii* Kom decreased significantly with the increase of NaCl concentration. The dry weight of *Nitraria tangutorum* Bobr and *Nitraria roborowskii* Kom was 41.4% and 53.9% of the control at 12% NaCl concentration respectively. At this time, the above-ground dry weight of *Nitraria tangutorum* Bobr and *Nitraria roborowskii* Kom decreased significantly with the increase of NaCl concentration. The dry weight of *Nitraria tangutorum* Bobr and *Nitraria roborowskii* Kom was 41.4% and 53.9% of the control at 12% NaCl concentration respectively. At this time, the above-ground dry weight dropped to the lowest level. It was clear that the salt tolerance of thorn was very high. Only when the concentration of NaCl was higher than 6%, the aboveground dry weight of *Nitraria tangutorum* Bobr and *Nitraria roborowskii* Kom was significantly reduced, while the aboveground dry weight of *Nitraria sibirica* Pall was always unchanged. The salt tolerance of the *Nitraria sibirica* Pall was significantly better than that of the *Nitraria tangutorum* Bobr and the *Nitraria roborowskii* Kom.

It could be seen from figure 7 that the underground fresh weight of *Nitraria tangutorum* Bobr and *Nitraria roborowskii* Kom did not change much at the salt concentration of 0-6%. When the salt concentration was greater than 6%, the underground fresh weight of *Nitraria tangutorum* Bobr and *Nitraria roborowskii* Kom decreased significantly, with the lowest being 40.9% and 34.5%, respectively, of the control group. However, with the increase of NaCl stress concentration, the *Nitraria sibirica* Pall fresh underground weight first increased and then decreased. Under the 9% NaCl stress, the fresh underground weight increased to the maximum value, which was 1.6 times of that of the control group. With the increase of salt concentration, the fresh underground weight decreased but showed no difference from the control group. The results showed that NaCl concentration greater than 6% could significantly inhibit the accumulation of fresh substances in the underground of *Nitraria tangutorum* Bobr and *Nitraria roborowskii* Kom, and the inhibitory effect was enhanced with the increase of the stress concentration. NaCl stress had little effect on the fresh weight in the underground of *Nitraria sibirica* Pall, and low-concentration NaCl could significantly promote the accumulation of fresh substances in the underground of *Nitraria sibirica* Pall.

![Figure 7](image_url) NaCl stress on 3 kinds of *Nitraria* underground fresh weight.

As could be seen from figure 8, the underground dry weight of *Nitraria tangutorum* Bobr and *Nitraria sibirica* Pall increased first and then decreased with the increase of NaCl stress concentration. Under the stress of 0-6% NaCl, the underground dry weight of *Nitraria tangutorum* Bobr and *Nitraria sibirica* Pall increased and reached the maximum at 6% and 3% NaCl respectively, which was 1.2
times and 2.4 times of the control group. Under the concentration of 9-15\% NaCl, *Nitraria tangutorum* Bobr and *Nitraria roborowskii* Kom were reduced to 50.4\% and 22.8\% of the control group respectively, while *Nitraria sibirica* Pall was not different from the control group. This indicated that low concentration NaCl had a promoting effect on the accumulation of dry weight underground of *Nitraria tangutorum* Bobr and *Nitraria sibirica* Pall, and the promoting effect on *Nitraria sibirica* Pall was more obvious. NaCl had a strong inhibitory effect on the accumulation of dry matter of *Nitraria tangutorum* Bobr and *Nitraria roborowskii* Kom, and had a stronger inhibitory effect on *Nitraria roborowskii* Kom.

**Figure 8.** NaCl stress on 3 kinds of *Nitraria* underground dry weight.

**Figure 9.** NaCl stress on 3 kinds of *Nitraria* relative root shoot ratio.

From the change trend, the plant weight of *Nitraria sibirica* Pall changed relatively little, the fresh
weight on the ground decreased slightly, and the rest fluctuated slightly. The dry and fresh weight of the plants of *Nitraria tangutorum* Bobr and *Nitraria roborowskii* Kom decreased rapidly when the salt concentration was 3-9% NaCl. When NaCl concentration was 6-9%, the variation of plant weight of *Nitraria roborowskii* Kom was the largest, and 6% NaCl concentration could be the sensitive concentration. The dry weight variation of *Nitraria tangutorum* Bobr seems to have the same trend. Overall, the *Nitraria sibirica* Pall was better than the other two kinds of *Nitraria*.

As could be seen from figure 9, with the increase of stress concentration, *Nitraria tangutorum* Bobr was no significant difference in the ratio of roots to crowns, but the *Nitraria roborowskii* Kom kept decreasing, while the *Nitraria sibirica* Pall first increased and then decreased. Under the stress of 0-6% NaCl, there was no significant change in the *Nitraria roborowskii* Kom, while under the stress of 3% NaCl, the *Nitraria sibirica* Pall reached the maximum value, 1.9 times higher than the control group. When the concentration of NaCl was more than 6%, the *Nitraria roborowskii* Kom decreased significantly, the lowest was only 28.1% of the control, but the *Nitraria sibirica* Pall had no significant difference from that of the control. NaCl stress had a significant inhibitory effect on the ratio of root to crown of *Nitraria roborowskii* Kom, which inhibited root growth more. The root to crown ratio of *Nitraria tangutorum* Bobr was increased, which was related to the small effect of salt on the root growth and the large decrease of overground growth. The effect of low concentration on the ratio of root to crown of *Nitraria sibirica* Pall was greater than that of high concentration.

### 3.6. 3 species of Nitraria growth index comprehensive analysis of salt resistance

From the above results, it could be seen that NaCl stress had a certain impact on the changes of relative plant height, relative number of leaves, relative stem diameter and relative leaf area (except for the change of relative stem diameter of *Nitraria roborowskii* Kom) as well as the changes of relative weight of plants of *Nitraria tangutorum* Bobr, *Nitraria roborowskii* Kom and *Nitraria sibirica* Pall. 0-6% low concentration of NaCl stress except plant height and stem diameter index inhibition for the growth of other, smaller plant weight change of *Nitraria sibirica* Pall and more obvious role in promoting. The results showed that the growth indexes of *Nitraria tangutorum* Bobr and *Nitraria roborowskii* Kom were obviously inhibited when 6% NaCl was greater than that of *Nitraria sibirica* Pall, but the plant weight of small fruit was not affected obviously, and the relative weight of the plant changed little.

According to the relative changes in plant height, stem diameter, number of leaves, leaf area, average fresh weight of plants, average dry weight of plants and other growth indexes of the three *Nitraria* species under NaCl stress, the average value of their membership function under 5 NaCl concentrations of 3-15% was calculated and the salt-tolerance was analyzed [15-21]. All indexes were given equal weight. The results were as follows:

| Plant                          | Average Value | Salt tolerant sorting |
|-------------------------------|--------------|-----------------------|
| *Nitraria tangutorum* Bobr    | 0.137        | 3                     |
| *Nitraria roborowskii* Kom    | 0.816        | 2                     |
| *Nitraria sibirica* Pall      | 0.500        | 1                     |

It could be seen from table 1 that the average value of membership function of *Nitraria sibirica* Pall was the highest, far higher than the other two species. Therefore, according to the growth
condition of the plant, the Nitraria sibirica Pall was the most salt-tolerant, ranking the first, and the Nitraria roborowskii Kom was the second, ranking the second. Nitraria tangutorum Bobr was the worst, third in order.

4. Discussion

4.1. Single index analysis and comprehensive index analysis and salt tolerance of plants

In this experiment, there was no significant change in the increase of the relative stem diameter of Nitraria roborowskii Kom under NaCl stress, while Nitraria sibirica Pall and Nitraria tangutorum Bobr were more sensitive to NaCl stress. However, by considering the plant height, leaf number, leaf area, average fresh weight, average dry weight, and comprehensive membership function of 3 Species of Nitraria. Nitraria sibirica Pall was more salt-tolerant than Nitraria tangutorum Bobr and Nitraria roborowskii Kom. Ha et al., Xu et al, after analyzed each growth index, all believed that the comprehensive analysis results of each index were more reliable.

4.2. Comparison of salt tolerance between three species of Nitraria and other species of Nitraria

Due to the time limitation, only the salt tolerance of Nitraria tangutorum Bobr, Nitraria roborowskii Kom and Nitraria sibirica Pall were analyzed in this study. According to the reports of other researchers, such as zhang li and wu xiang, etc., the comprehensive evaluation by the membership function method showed that the salt-tolerance of the three kinds of Nitraria, from the largest to the smallest, the Nitraria sibirica Pall., the Nitraria tangutorum Bobr and the Nitraria roborowskii Kom. By referring to previous studies, it was believed that the salt-tolerance of Nitraria sibirica Pall was also stronger than that of Nitraria roborowskii Kom., which may be similar to or higher than that of Nitraria sibirica Pall.

4.3. Relationship between plant growth indexes and salt tolerance

In this study, six plant growth indexes were determined, and there were some differences among the indexes. Generally, the dry and fresh weight of the plant in the growth index could better reflect the growth characteristics or conditions of the plant. For example, Zhang et al concluded that under salt stress, fresh weight water content and dry weight water content of different varieties all decreased. Fu et al concluded that with the increase of salt stress intensity, plant height, fresh weight and dry weight of the two types of inbred lines presented a gradually declining trend. Ren concluded that the salt stress treatment had a great influence on the characters of wheat seedlings at different seedling stages, ranging from fresh weight and dry weight above ground. Therefore, in the comprehensive analysis, such as the calculation of the comprehensive membership function, the weight of indicators such as the dry matter weight of plants can be increased.

5. Conclusion

- NaCl stress had the greatest inhibitory effect on the plant height growth of Nitraria tangutorum Bobr, followed by Nitraria sibirica Pall, and finally Nitraria roborowskii Kom.
- With the increase of NaCl stress concentration, the number of leaves of Nitraria tangutorum Bobr decreased rapidly, and the number of leaves of Nitraria roborowskii Kom decreased rapidly when the salt concentration was greater than 6%. The relative number of leaves of Nitraria sibirica Pall was significantly reduced at 15% salt concentration.
- With the increase of salt concentration, the relative increase of stem diameter of Nitraria tangutorum Bobr was decreased in the first place, Nitraria sibirica Pall was decreased in the second place, but Nitraria roborowskii Kom was not significantly affected.
- With the increase of salt concentration, the relative leaf area of Nitraria tangutorum Bobr decreased significantly. The relative leaf area of Nitraria roborowskii Kom increased significantly at 6% and then decreased significantly. The relative leaf area of Nitraria sibirica Pall decreased significantly at 12%.
With the increase of salt concentration, the dry weight and fresh weight of the plant, the weight of the *Nitraria sibirica* Pall decreased little, there was no significant difference, the rest fluctuated slightly up and down; The changes of *Nitraria tangutorum* Bobr and *Nitraria roborowskii* Kom were more consistent.

- NaCl stress had the least effect on the fresh weight of *Nitraria sibirica* Pall, and the changes of *Nitraria tangutorum* Bobr and *Nitraria roborowskii* Kom were basically the same. Under the salt stress of different concentration, the dry weight of *Nitraria sibirica* Pall had no obvious change.

The comprehensive membership function analysis of the growth indexes showed that the salt tolerance order was successively *Nitraria sibirica* Pall > *Nitraria roborowskii* Kom > *Nitraria tangutorum* Bobr

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