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The effect of salt stress on the chlorophyll level of the main sand-binding plants in the shelterbelt along the Tarim Desert Highway

XU XinWen[1†], XU HaiLiang[1], WANG YanLing[2], WANG XiaoJing[1], QIU YongZhi[3] & XU Bo[3]

[1] Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, China;
[2] Institute of Environmental Engineering, Xinjiang Agricultural University, Urumqi 830052, China;
[3] Tarim Branch, PetroChina Company Limited, Korla 841000, China

Based on the fact that only high saline water irrigated to the shelterbelt along the Tarim Desert Highway, the experiment about three species with six degree of salinity was carried out to analyze the relation between chlorophyll content and salt stress. The results show that: (1) the chlorophyll content of tree species decreases with aggravating the salt stress, which explains that salt stress can affect chlorophyll accumulation of three plants; (2) from chlorophyll content with different salinity, the chlorophyll content of three shrubs also has twice obvious decrease, which indicates that some plants adapt to salt stress. We divided salt resistance of the plant into three grades, namely the slight salt resistance, the heavy salt resistance and the extreme salt resistance; and (3) according to the experimental results, the salt stress of each plant was divided, which can provide theoretical guidance for constructing the shelterbelt along the Tarim Desert Highway.

artificial shelterbelt, sand-binding plants, salt stress, chlorophyll

The anti-salt mechanism of plants has been extensively studied, and the shape development, photosynthesis, and carbon metabolization of plants under salt stress have been investigated[1–6]. Chlorophyll is the main color agent responsible for photosynthesis. Under adverse circumstances, the chlorophyll level is a good indicator of the photosynthesis function. It has been found that the chlorophyll level of trees decreases with aggravated salt stress[7] due to enzymatic chlorophyll degradation[8,9]. However, the chlorophyll level of the major sand-binding plants under extreme conditions has not been previously investigated.

The 562 km Tarim Desert Highway connects Lunnan to Minfeng through the depopulated area in the Taklimakan Desert. To reduce blown sand disaster and improve the environment, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences and Lanzhou Institute of Desert Research of Chinese Academy Sciences proposed the shelterbelt construction along the highway. In 2001 at Tazhong 4 Oil Field, the shelterbelt demonstration zone with a length of 30.8 km was successfully built. The Tarim Desert Highway ecological shelterbelt project was later fully launched in 2003 and completed in 2006. The 436 km shelterbelt formed a green corridor in the Taklimakan Desert.

The environmental conditions are extremely odious along the desert highway. In particular, the salinity of irrigation water is very high, and the plant adaptability to the water quality is a serious concern. By investigating the effect of irrigation with high salinity water on the plant chlorophyll level of the sand-binding plants in the

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†Corresponding author (email: sms@ms.xjb.ac.cn)
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highway shelterbelt, this paper provides a scientific basis for the construction, management and protection of the desert highway shelterbelt.

1 Site profile

The Taklimakan Desert, located in the continental temperate and arid desert climate zones, is the largest mobile desert in the world, with a total area of about 33.76×10^4 km^2. According to the Tazhong Weather Station, the local climatic characteristics are: the annual average temperature of 12.4℃, the maximum temperature in summer of 45.6℃ and the minimum temperature in winter of –22.2℃, the annual rainfall of less than 50 mm and the annual evaporation potential over 3500 mm. The Taklimakan Desert is the most arid area in China. The landform types are mainly mobile sand dunes, such as crescent dunes, compound chain dunes, complex longitudinal ridges, pyramid dunes, fish scale-like dunes and dome dunes. The windblown sand activities are frequent and strong.

To monitor the dynamic change of groundwater quality, 26 groundwater monitoring wells were set up in 2003 along the desert highway. In Figure 1, the transverse axis is mileage of the desert highway; the vertical axis is mineralization of the groundwater. The figure shows that the range of mineralization is 4—28 g/L, along the highway, the middle part is higher than the other. So, salt stress should be considered in choosing plant type and managing the shelter forest ecological project.

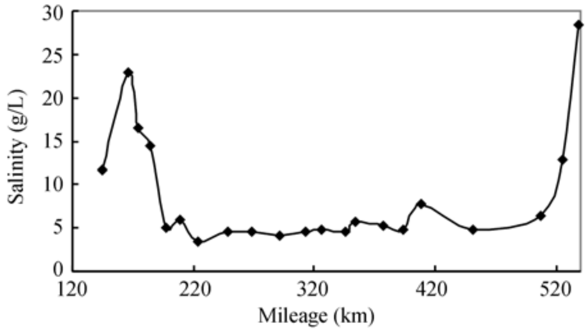

Figure 1 The salinity distribution of the groundwater along the Tarim Desert Highway.

2 Experimental methods

The experimental field is located in the hinterland of the Taklimakan Desert. Six test plots of identical environmental condition were chosen. The yearling seedlings of three sand-binding plants, *Holocylon persicum*, *Tamarix ramosissima*, and *Calligonum leucocladum*, were explored at six levels of salinity in the test plots. The number of trees and rows was identical in each test plot. The irrigation water salinity of each plot was: No.1 plot, 0 g/L; No.2 plot, 5 g/L; No.3 plot, 10 g/L; No. plot, 15 g/L; No.5 plot, 20 g/L; No.6 plot, 27.9 g/L. The test plots were irrigated every 10 days from early April to the end of September. The plant growth was then recorded, and one-year leaves were collected at the same height of each tree. A sufficient amount of leaves were collected and sealed in plastic bags, immediately stored in a freezer, and analyzed within 12 h.

The analysis was performed according to Zhao's method[10]. Fresh leaves were killed (105℃, 10 min), dried (60℃), and finely pulverized after removal of the main veins. Chloroplast pigments were extracted with 80% acetone and partitioned between ether and distilled water. The pigment solution in ether was then submitted to analysis.

3 Results and discussions

The growth of the shelterbelt plants is shown in Table 1. From that, the maximum growth of *Holocylon persicum* was achieved at 5 g/L salinity, and the growth was adversely affected at higher salinity. The maximum growth of *Tamarix ramosissima* was achieved at 2 g/L salinity, and the growth reduced steadily when the salinity was higher than 10 g/L. The maximum growth of *Calligonum leucocladum* was achieved at 5 g/L salinity, and the growth reduced sharply at higher salinity. The results showed that *Calligonum leucocladum* was sensitive to the irrigation water salinity.

The chlorophyll levels of the three plants were also summarized (Figure 2). When the salinity was more than 10 g/L, the chlorophyll levels of all plants declined. The

Table 1 The average plants height under saline water irrigation (cm)

Salinity (g/L)	2	5	10	15	20	27.9
Holocylon persicum	142.8	186.2	170.5	156.3	156.5	129.6
Tamarix ramosissima	57.5	51.0	52.2	39.8	42.7	40.6
Calligonum leucocladum	222.2	226.2	160.8	146.7	66.8	50.4

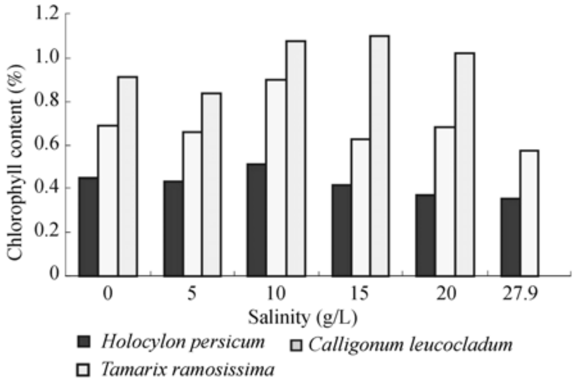

Figure 2 The chlorophyll content of three type of sand-controlling plant spies in different salinities.

chlorophyll level of *Calligonum leucocladum* dropped by 30%, but the salinity increased from 10 g/L to 15 g/L. The findings confirmed that high salt stress results in the reduction of the chlorophyll level[11].

The degree of salt stress was evaluated by calculation of the change rate of the chlorophyll level under different salinity by the formula:

$$V = (H_2 - H_1)/(S_2 - S_1), \quad (1)$$

where V is the change rate, H_2 and H_1 are the salinities, and S_2 and S_1 are the corresponding chlorophyll levels. The calculation results are presented in Figure 3.

The degree of salt stress can be classified into three types. Under slight salt stress, the chlorophyll level re-

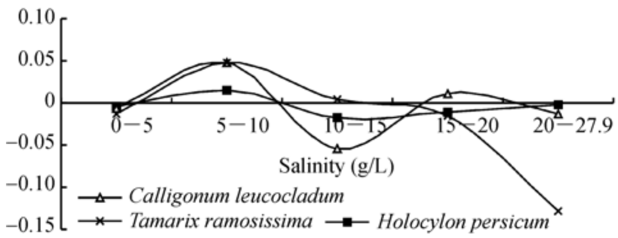

Figure 3 The variation of chlorophyll content in different salinity.

mains stable or increases steadily, and the plant grows well. The plants *Tamarix ramosissima* and *Haloxylon ammodendron* are under slight salt stress at <10 g/L salinity, and the *Calligonum leucocladum* is under slight salt stress at <5 g/L salinity. Under severe salt stress, the chlorophyll level steadily decreases, and the plant's growth declines. The plants *Tamarix ramosissima* and *Haloxylon ammodendron* are under severe salt stress when the salinity is 15−27.9 g/L, and the *Calligonum leucocladum* is under severe salt stress when the salinity is 10−15 g/L. Under extreme salt stress, the chlorophyll level decreases sharply and the plant growth is seriously inhibited. The plants *Tamarix ramosissima* and *Haloxylon ammodendron* are under extreme salt stress when the salinity exceeds 27.9 g/L, and the *Calligonum leucocladum* is under extreme salt stress when the salinity exceeds 20 g/L.

4 Conclusions

The sand-binding plants adapt to salt stress through adjusting chlorophyll level, and the decline rate of chlorophyll is dependent on the plant species. The salt tolerance of the major plants in the shelterbelt along the Tarim Desert Highway has been determined. The plant *Calligonum leucocladum* grows well at a salinity below 5 g/L, suffers from severe salt stress at a salinity of 10−15 g/L, and is seriously harmed when the salinity is above 20 g/L. The plants *Haloxylon ammodendron* and *Tamarix ramosissima* grow well when the salinity is below 10 g/L, and suffer from salt stress when the salinity is 15−27.9 g/L. This information will be useful for the irrigation management for the shelterbelt plants of the desert highway.

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