Probe - Plant & Animal Sciences 2021, 3(1), 1387.
https://doi.org/10.18686/ppas.v3i1.1387

Article

Research of salt tolerance mechanism of sandy shrub *Tamarix* spp

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CITATION

Liu H. Research of salt tolerance mechanism of sandy shrub *Tamarix* spp. Probe - Plant & Animal Sciences. 2021; 3(1): 1387. https://doi.org/10.18686/ppas.v3i1.1387

ARTICLE INFO

Received: 19 May 2021
Accepted: 23 June 2021
Available online: 22 August 2021

Abstract: 6.5% of the world's total land area is saline-alkali land, and more than 800 million hectares of saline soil are distributed worldwide. Soil salinization has become an important constraint on global food security and ecological security. *Tamarix* is a typical salt-secreting halophyte, which can excrete the salt in the plant from the body. The use of plant resources to transform saline-alkali soils has fundamentally alleviated soil salinization compared with traditional methods. Therefore, the research on the salt tolerance mechanism of tamarisk is very important to alleviate the problem of the shortage of cultivated land resources.

Keywords: *Tamarix*; salt stress; plant physiology

1. *Tamarix* and soil salinization

1.1. *Tamarix*

Tamarix is a perennial shrub or small tree of the *Tamarix* Linn. family (Tamaricaceae). There are about 90 species coexisting in the world. It is widely distributed as a dominant species in arid and semi-arid deserted land and saline-alkali areas. There are 18 species and 2 varieties in my country, which are mainly distributed in the arid, semi-arid and coastal saline areas of North China.

During the long-term evolution of *Tamarix*, it has formed the characteristics of drought resistance and salt-alkali tolerance. It has a perfect salt secretion system, which can effectively excrete salt ions from the surface of the stems and leaves. Therefore, they can be at a salt-alkali content of 0.5% to 3%. Land growth is an excellent tree species for preventing soil erosion and improving saline-alkali land. *Tamarix* is not only an important ecological tree, but also has ornamental value, medicinal value and economic value. *Tamarix* is resistant to pruning and has a long flowering period. It is often planted as a garden landscape plant. Its branches can be used for weaving, and its fine branches and leaves can be used as traditional Chinese medicine. Studies have shown that the service value of the natural tamarisk shrub ecosystem with an area of 22,300 hm^2 ranges from 297.058 billion to 297.462 billion yuan per year, with an average of 297.260 billion yuan per year, of which the value of climate regulation is 294.427 billion yuan and the degradation of pollutants The value is 203 million yuan, which will increase the value of 126 million yuan in terms of biodiversity, and the value of 106.4 million yuan in terms of soil formation and protection [1].

1.2. Status of soil salinization

At present, due to global warming, rising sea levels and other natural factors as well as increasing industrial pollution, unreasonable land use and other human factors, soil salinization and secondary salinization are becoming more and more serious. It is estimated that by 2050, the world More than 50% of the cultivated land area will be salinized [2]. Soil salinization has become an important constraint on global food security and ecological security. Soil salinization and secondary salinization will cause the osmotic pressure of the soil solution to increase, the aeration and water permeability of the soil will become worse, and the availability of nutrients will decrease. Both will cause plants to fail to grow normally, degrade the surface vegetation community, reduce ecological stability, and sharply reduce the area of arable land, which directly affects regional ecological, economic and social benefits, and restricts regional sustainable development.

According to statistics from the second national census organized by the Ministry of Agriculture and Rural Affairs, China's total saline soil area accounts for 4.88% of the country's available land area, of which the salinized area of arable land accounts for 6.62% of the country's total arable land [3]. The large area and wide distribution of saline soil in my country are rare in the world.

2. Morphological adaptation of tamarisk salt tolerance

2.1. Adaptation of *Tamarix* leaves to salt stress

Leaf sclerosis and leaf degradation are typical ways for halophytes to adapt to the salt environment. Most halophytes have epidermal hairs, glandular hairs, wax coats, tumor-like or milky protrusions, and some halophytes have degenerated leaves, developed fence tissues, and glands. The number of hairs increases with the increase of salt concentration, the outer wall of stem epidermal cells is thickened, the cells are tightly arranged, and the stomata sink [4]. *Tamarix* leaves are composed of three parts: epidermis, cortex, and vascular column. The epidermis has sunken stomata and salt glands. The petioles are degenerated and cling to the stems to form a stem-leaf complex. *Tamarix* leaves are distributed with palisade tissue on the inside of the epidermis. The lower epidermis is more developed than the upper epidermis and contains a lot of chloroplasts; the epidermal cells protrude outward to form papillae of varying heights, covered with stratum corneum. These morphological structures play an important role in reducing transpiration and excretion of salt in tamarisk [5].

2.2. Adaptation of *Tamarix* salt gland structure to salt stress

Tamarix is a typical salt-secreting halophyte, with salt glands composed of 6 secreting cells and 2 collecting cells. *Tamarix* salt glands develop from the original epidermal cells, mainly distributed on the leaves and assimilation branches, and sink into the epidermis. When the glands are completely formed and secrete salt, the cell walls of the secretory cells extend to the cytoplasm to form rod-shaped protrusions; there are a large number of mitochondria in the secretory cells and a large number of plasmodesmata between the secretory cells and the collecting cells. This special salt gland structure determines the strong secretion of tamarisk salt glands. In order to adapt to the salty environment, the salt gland increases the density of the salt gland on the one hand, and on the other hand increases the salt secretion rate of a single salt gland. The salt that enters the plant body is transported to the salt-secreting glands, and excreted out of the body through the secretory cells, protecting itself from ion poisoning [6].

2.3. Root adaptation to salt stress

In addition to the regulation of above-ground structures such as leaves, stomata, salt glands, etc., xerophyte halophytes usually have a developed root system, which helps plants maintain normal metabolism and growth under salt stress environments. The root system of *Tamarix* is extremely developed, and the main root can penetrate deep into the groundwater layer. With the increase of salt concentration, the deeper the root of *Tamarix*, the root-to-shoot ratio increases significantly. Under different salt conditions, the above-ground biomass and root biomass of *Tamarix* maintain a constant ratio, which indicates that *Tamarix* can adapt to changes in external environmental conditions by adjusting its biomass distribution ratio and improve its viability [7].

3. Physiological mechanism of salt tolerance in *Tamarix*

3.1. Salt tolerance and photosynthesis of *Tamarix*

Photosynthesis is an important way for plants to obtain energy, and chlorophyll is the main substance for plants to carry out photosynthesis. Under salt stress environment, due to the increase of salt ion content in plant leaves, it promotes the dissociation of chlorophyll and chloroplast protein, resulting in the decomposition of chlorophyll and the reduction of photosynthetic rate. Chlorophyll content is often used as an important indicator to measure the photosynthetic function of leaves. Studies have found that with the increase of salt stress, the chlorophyll content in *Tamarix* will increase first and then decrease, indicating that *Tamarix* can adapt to salt stress by increasing the chlorophyll content, while excessive salt stress will destroy the synthesis of chlorophyll, while salt stress promotes The degradation of chlorophyll by chlorophyllase leads to a decrease in chlorophyll content [8], and the stronger the stress, the longer it takes for *Tamarix* to adjust itself [9].

3.2. Salt tolerance and osmotic adjustment of *Tamarix*

Osmotic adjustment is an important physiological mechanism for plants to resist salt stress in a saline environment. Plants are subjected to osmotic stress and ion poisoning under salt stress. Higher plants do this by adjusting the absorption ratio, quantity and accumulation of inorganic ions, which are non-toxic to the cell's organic osmotic adjustment substances (proline, soluble sugar, betaine, soluble protein, etc.). Osmotic adjustment to enhance its salt tolerance. With the accumulation of salt, the contents of Na^+ and Cl^- in *Tamarix* gradually increase, while K^+, Ca^{2+} and Mg^{2+} show a downward trend, indicating that the absorption and accumulation of various ions present a balance between the absorption and accumulation of various ions. Under the same salt level, the content of Na^+ and K^+ in *Tamarix* lanceolata is in the order of leaf>root>stem, and the content of Na^+ is always greater than K^+, indicating that the leaves are the main part of accumulation of Na^+ and K^+. The transmission of stems prevents other parts from appearing cumulative effect of salt ions [10]. The accumulation of organic osmotic adjustment substances can maintain the normal turgor pressure and physiological metabolism of plant cells in a salt stress environment to a certain extent, and is non-toxic to cells and has no inhibition on metabolism. Relevant studies have shown that the proline content, soluble sugar, and betaine content of the leaves of Chinese *Tamarix* increase with the increase of salt concentration, which shows that proline and soluble sugar play an important role in the high-salt environment of *Tamarix*. And soluble protein is not the main organic osmotic adjustment substance [11].

3.3. Salt tolerance and antioxidant mechanism of *Tamarix*

The saline environment breaks the dynamic balance mechanism between the continuous production and removal of reactive oxygen species (ROS) in plants, causing oxidative damage. Therefore, the activity of antioxidant enzymes is often used as a consideration for the ability of plants to tolerate salt. Standards. Studies have found that the activities of *Tamarix* peroxidase (POD), catalase (CAT) and superoxide dismutase (SOD) increase under low salt concentration (≤ 100 mmol/L). High, so as to effectively remove excess ROS and keep malondialdehyde (MDA) at a low level; however, as the concentration of NaCl increases (≥ 200 mmol/L), the activity of SOD and POD weakens, leading to continuous ROS Accumulation, membrane lipids are peroxidized [12,13], membrane permeability increases, intracellular lysate is extravasated, and finally plant tissues are destroyed [14]. Enhancing the activity of antioxidant enzymes in the body and improving the level of antioxidant metabolism are important methods to improve the salt tolerance of *Tamarix*.

4. Molecular regulation mechanism of salt tolerance in *Tamarix*

At the molecular level, the expression status of certain genes in plants changes under salt stress. Relevant studies have shown that the promoter sequence of the Tamarisk transcription factor gene ThbHLH contains DOF, Ibox, W-box and other cis-acting related to stress resistance. Element, transfer ThbHLH into Arabidopsis, can significantly reduce O_2^- and H_2O_2 levels [15]. And the transcription factor ThCRF1 can be combined with TTG, DRE, GCC and other motifs to induce the expression of genes such as pyrrole-5-carboxylic acid synthase (P5CS), trehalose-6-phosphate phosphatase (TPP), SOD and POD, thereby Increase the content of proline and trehalose, and enhance the activity of POD and SOD [16].

5. Outlook

In the face of increasingly severe soil salinization worldwide, it is urgent to find a scientific, effective and sustainable way to improve soil. *Tamarix* has the characteristics of salt tolerance and has a good effect on the improvement of salinized soil. In recent years, the research on the resistance mechanism of *Tamarix* and the cloning of related genes has given people a more comprehensive understanding of the mechanism of plant salt tolerance. In future research, efforts will be made to examine the physiological phenotypes of different species of *Tamarix* under salt stress. Analyze the gene phenotype and obtain the resistance genes that affect the salt tolerance of Tamarisk, which provides a theoretical basis for the cultivation and promotion of Tamarisk.

Conflict of interest: The authors declare no conflict of interest.

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