Acta Ecologica Sinica 36 (2016) 433–441

Contents lists available at ScienceDirect

Acta Ecologica Sinica

journal homepage: www.elsevier.com/locate/chnaes

Effects of salinity and water stress on the physiological and ecological processes and plasticity of *Tamarix ramosissima* seedlings

Ruiqun Zhang [a], Xiaodong Ma [a,b,*], Minghui Wang [a], Haohao Lv [a], Chengang Zhu [b]

[a] *Xinjiang Normal University, Urumqi Xinjiang Special Environmental Diversity Control and Application Key Laboratory of the Autonomous Region, Urumqi 830054, China*
[b] *State Key Laboratory of Desert and Oasis Ecology, Xinjiang Institute of Ecology and Geography, 830011 Urumqi, China*

ARTICLE INFO

Article history:
Received 11 May 2015
Received in revised form 8 October 2015
Accepted 7 December 2015

Keywords:
Tamarix ramosissima seedlings
Salt stress
Water stress
Photosynthetic characteristics
Anatomical characteristics
Plasticity

ABSTRACT

Tamarix ramosissima grows in extremely arid areas and is a dominant species of desert riparian forests in the lower reaches of the Tarim River. Using a single factor control test with indoor potted plants, *T. ramosissima* seedlings were treated with either salt or water stress, and compared to a control treatment. For salt stress, plants were treated with one of five salinity gradients: a control group with no salt stress (S0); light salt stress (S1); moderate salt stress (S2); middle, and high salt stress (S3); and high salt stress (S4). In addition, five moisture gradients were employed: groups D0, D1, D2, D3, and D5 (flooding), for which soil water contents were 75%, 55%, 35%, 15% field water capacity, and flooding, respectively. Combined treatments with both salt and water stress were not performed. The goal of the present study was to analyze the effects of salt and water stress on *T. ramosissima* seedlings by measuring photosynthetic characteristics, anatomical structure, and morphological plasticity characteristics, such as height, crown breadth, epidermis, and changes to the cortex, vascular cylinder etc. Because structure provides the basis for function, the anatomical structure of desert plants can be indicative of their photochemical efficiency. The results showed that: 1) salt and water stress resulted in relatively lower growth rates, biomass, and smaller plant height and crown width of *T. ramosissima* seedlings. In addition, the root to shoot biomass ratio initially increased and then decreased rapidly. Salt stress adversely affected seedling growth to a greater extent than water stress did ($P < 0.05$). 2) No significant differences were observed in the S1, D1, and S2 treatments. Fluorescence parameters decreased significantly ($P < 0.05$), and photochemical efficiency and photosynthetic activity were inhibited in the S3 and D2 treatments. With increasing stress, the chlorophyll and the leaf water contents decreased suggesting that increased stress is not conducive to normal development. 3) Salt and water stress both affected the xylem conduits of *T. ramosissima* seedlings. Under salt stress, the diameters of the root xylem vessels were significantly smaller than that of the control group, and vessel densities were significantly higher than that of control group. The opposite trends were observed under water stress. The percentage of total diameters of epidermal and palisade tissue, and the cortical thickness of seedlings increased under water stress, all adaptations that are favorable for water retention and improved photosynthetic efficiency. 4) The height growth rate, chlorophyll content, leaf cuticle thickness, assimilating branches, and the root plasticity index were greatest under conditions of either salt or water stress. Seedlings were more tolerant to water stress than to salt stress. The mean plasticity indexes could be classified as root > assimilating shoots > leaf under salt stress, and leaf > root > assimilating branches under water stress. In summary, *T. ramosissima* seedlings were better adapted to low levels of stress as observed in the S0 and D1 treatments. Compared to water stress, salt stress is a more critical ecological factor that is important to inhibition of the growth of *T. ramosissima* seedlings.

1. Introduction

Tamarix ramosissima is widely distributed in the northwest arid areas in China, and shows strong salt and drought resistance. *T. ramosissima* is the dominant species in the desert riparian forest that grows around the lower reaches of the Tarim River, one of the main continental rivers in China. This plant has a very important role in maintaining and restoring the desert riparian ecosystem in the region [1]. The climate in the lower reaches of the Tarim River is extremely arid, and the depth of the groundwater table decreases markedly during the dry season. The lowering of the water table, along with increased water use by the human population in upstream regions, has intensified soil desertification and salinization in the lower reaches of the Tarim

* Corresponding author at: Xinjiang Normal University, Urumqi Xinjiang Special Environmental Diversity Control and Application Key Laboratory of the Autonomous Region, Urumqi 830054, China.
E-mail address: mxd1107@126.com (X. Ma).

http://dx.doi.org/10.1016/j.chnaes.2016.09.006

Table 1
Effect of salt stress and water stress on growth of *Tamarix ramosissima* (mean ± SE).

Stress levels	Rate of plant height increase /%	Rate of plant crown breadth increase /%	Biomass /g	Root shoot ratio R/S
CK (S0)	1.308 ± 0.131a	30.6 ± 10.237a	0.200 ± 0.021a	0.300 ± 0.073a
S1	0.389 ± 0.121b	24.43 ± 8.75b	0.134 ± 0.014b	0.845 ± 0.219b
S2	0.172 ± 0.067b	17.27 ± 4.46b	0.112 ± 0.001b	1.007 ± 0.287b
S3	0.198 ± 0.061b	12.03 ± 0.517b	0.060 ± 0.008c	0.639 ± 0.052b
S4	–	–	–	–
CK (D0)	1.308 ± 0.131a	30.6 ± 10.237a	0.200 ± 0.021ab	0.300 ± 0.073a
D1	1.152 ± 0.137a	36.6 ± 10.361a	0.303 ± 0.087b	0.747 ± 0.012b
D2	0.552 ± 0.109a	32.6 ± 10.146a	0.076 ± 0.013a	0.363 ± 0.026a
D3	–	–	–	–
D5	3.852 ± 1.441b	58.226 ± 8.842b	0.333 ± 0.074b	0.406 ± 0.003a

Different letters indicate significant differences ($P < 0.05$).

River. Because of the effects of water overflow, the closer to the river, the higher the soil salinity [2,3]. The dynamics of water and salt movements in the lower reaches of the Tarim River have greatly affected the germination and growth of *T. ramosissima* seedlings on the floodplain. A comprehensive management project in the Tarim Basin has been implemented since 2000, and ecological water transport has played an important role in raising the groundwater level. The movement of water during this process is beneficial for seed germination of *T. ramosissima*, but many seedlings are flooded during water movement, and the rapid loss of moisture from the soil surface results in the accumulation of salt. This can hinder seedling root development and delay or arrest the development of seedlings grown from late-germinated seeds. Salt and water stresses are the main factors affecting the survival and reproduction of plants derived from late-germinated seeds [4].

The salt and drought resistance of *Tamarix* can be attributed to the combined effects of various physiological and biochemical processes. Several studies have analyzed the photosynthetic, physiological, morphological, growth, and developmental responses to drought and salinity in *Tamarix* [1,2,5,6]. Phenotypic plasticity means that individuals with the same genotype can respond differently to different environmental conditions, resulting in different phenotypic characteristics [7]. Species with high phenotypic plasticity in terms of their morphology, growth, biomass allocation, and physiological and ecological characteristics are better able to obtain the necessary resources from their environment. Plants with high plasticity are more stress-tolerant, allowing them to grow in wider ecological ranges, thereby occupying a wide geographic range and more diverse types of habitats [8]. Studies on invasive *T. ramosissima* in riparian forests in the United States revealed that their roots showed high phenotypic plasticity, which enhanced their competitiveness to survive through extremely dry periods [9]. Other studies on the plasticity index (PI) of *T. ramosissima* adults found that the most important traits for ecological adaptation were the cuticle, palisade tissue, and leaf epidermal cells, as well as specialized adaptive structures to adapt to the desert environment [10]. Seedlings are most vulnerable, and seedling survival is the key to successful colonization. However, few studies have analyzed the stress tolerance of *T. ramosissima* seedlings. In this study, we analyzed the growth, photosynthetic physiology, and plasticity of the responses of *T. ramosissima* seedlings to salt and water stress. Our results reveal the ecological adaptation characteristics and strategies of *T. ramosissima* seedlings under environmental stress. These findings provide a theoretical basis for the ecological protection and restoration of the Tarim River basin and the surrounding arid region.

2. Materials and methods

2.1. Test materials and design

The lower reaches of the Tarim River lie between the southeastern Xinjiang Taklamakan Desert and Kuluke. This region is in a warm temperate zone with an extremely arid desert climate. The annual average rainfall is only 17.4–42.0 mm, but the average annual potential evaporation is as high as 2500–3000 mm. The climate is extremely dry, and the desert plants mainly rely on river water and groundwater for survival [11]. In the lower reaches of the Tarim River, desert riparian forest grows on both sides. Seeds of *T. ramosissima* were collected from this area in April 2014. Mature seeds were sown in pots (25 cm diameter × 30 cm height) and cultivated in a greenhouse. The substrate was Tarim downstream riparian sand, which was rinsed with water before use to remove salt. The soil salinity was 0.02% after rinsing. After seeds had germinated, the seedlings were thinned to 10 seedlings per pot. Seedlings were subjected to single-factor stress treatments when they reached 5 cm in height.

For the salt stress treatments, seedlings were treated with NaCl at increasing concentrations, as follows: control, no salt (CK, S0); light salt stress (S1); moderate salt stress (S2); high salt stress (S3); and very high salt stress (S4). The soil NaCl content in these treatments was: 0.02%, 0.2%, 0.5%, 0.8%, and 1.5%, respectively. Seedlings were watered

Table 2
Effect of water stress and salt stress on chlorophyll fluorescence parameter of *Tamarix ramosissima* seedlings (mean ± SE).

Treatments	Gradient	*Y*(II)	*ETR*	*Fv*/*Fm*	*Fv*/*Fo*
Salt stress	S0	0.725 ± 0.008b	53.767 ± 2.638a	0.796 ± 0.006a	3.908 ± 0.134a
	S1	0.724 ± 0.008b	67.354 ± 0.743b	0.792 ± 0.008a	3.871 ± 0.157a
	S2	0.69 ± 0.027ab	58.515 ± 2.252a	0.776 ± 0.006a	3.518 ± 0.108a
	S3	0.631 ± 0.027a	53.546 ± 2.277a	0.716 ± 0.05b	3.147 ± 0.456a
	S4	–	–	–	–
Water stress	D0	0.733 ± 0.004b	45.578 ± 0.261b	0.789 ± 0.004b	3.761 ± 0.096ab
	D1	0.724 ± 0.009b	45.998 ± 0.739b	0.784 ± 0.022b	3.619 ± 0.451ab
	D2	0.592 ± 0.046a	37.779 ± 2.911a	0.738 ± 0.009a	3.246 ± 0.119a
	D3	–	–	–	–
	D5	0.689 ± 0.01b	49.792 ± 0.73b	0.804 ± 0.013b	4.173 ± 0.276b

Different letters indicate significant differences ($P < 0.05$).