

Response of Growth and Physiological Characteristics and Root Soil Reinforcement of *Artemisia Ordosica* to Erosion Damage in Shendong Mining Area

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Abstract: To clarify the response mechanism of plant to root erosion damage in Shendong mining areas, *Artemisia ordosica* was taken as the research object, the response of growth and physiological indexes to root fracture and the effects of cyclic load of erosion force on the tensile properties of root were analyzed. The results showed that the net photosynthetic rate and transpiration rate of *A. ordosica* leaves decreased with increasing root breakage, the net photosynthetic rate decreased by 17.62%, 26.06% and 42.11%, the transpiration rate decreased by 11.97%, 25.98% and 51.15% after mild, moderate and severe damage, respectively, compared with the control. Compared with the control, the water use efficiency of light, moderate and severe damage increased by 5.39%, 10.74% and 38.43%, respectively; root disruption significantly inhibited the growth of *A. ordosica*, the growth rate of height, crown width, branch length and diameter decreased by 38.91%, 42.61%, 68.10% and 65.84%, respectively after severe damage compared with the control.

1 Materials and methods

1.1 Overview of the study area

The research area is located at the junction of Shenmu County, Yulin City, Shaanxi Province and Yijinhualuo Banner, Ordos City, Inner Mongolia, and is the coal mining subsidence control area of Shendong Mining Area. The climate in this region is characterized by the same period of rain and heat. The rainfall is concentrated in summer and autumn, and spring and winter are dry and windy. The annual average temperature is 8.9°C, the annual average precipitation is 396mm, the annual average evaporation is 1790mm, and the annual average wind speed is 3.5m/s. The soil in this area is mainly aeolian sandy soil with poor structure and low organic matter content. Common vegetation includes *Caragana microphylla*, *Artemisia ordosica*, *Hippophae rhamnoides*, *Setaria viridis*, *Stipabungeana*, etc.

1.2 Experimental design

1.2.1 Whole plant root system fracture test

Randomly select 2-3 years old black *Artemisia annua* in the research area, measure its growth indicators such as plant height, crown width, and basal diameter, and calculate the mean as the basis for standard plant selection.

The basic characteristics are shown in Table 1. The horizontal distribution range of the root system of *Artemisia ordosica* is 50-100cm, and it is densely distributed in the 0-30cm soil layer. The distribution of the root system is relatively small in the 40cm soil layer, and the only root system has not yet fully developed, with a small root diameter. Select similar black *Artemisia annua* as the test plant based on the standard plant size. Draw a circle on the surface with the diameter of the test plant as the center and a radius of 1m. Make two intersecting lines perpendicular to each other to divide the circle into four equal sections. Select a fan shape and excavate 0.5m downwards. During the excavation process, the root system that appears will be cut off using branch scissors. About 25% of the artificially formed root system will break, which is considered mild damage. After the root is cut off, the original soil will be buried and compacted; Select 2 sectors for excavation and cut off the root system, resulting in approximately 50% root system fracture, which is considered moderate damage; Select 3 sectors for excavation and cut off the root system, resulting in approximately 75% root system fracture, which is considered severe damage. Meanwhile, select the undamaged test strains as the control. There are 20 plants with mild, moderate, severe damage, and control, with a total of 80 test samples. Before the experiment, healthy branches were selected for labeling and growth indicators were measured. The photosynthetic parameters of the plants were measured on the 1st, 3rd, 4th, 6th, 7th, 10th, 13th, 20th, 28th, 44th, and 75th days after root damage, and the growth indicators of each tested plant were

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measured again on the 75th day.

Table 1 Growth state in standard strains of *Artemisia ordosica*

Indicator type		Standard strain of <i>Artemisia ordosica</i>				
Index of above-ground growth	Density (plant/m ²)	Coverage (%)	Plant height(m)	Crown width (m ²)	Base diameter(cm)	No. of branches
	0.20	0.15	0.34±0.11	0.25±0.08	0.45±0.17	22±6
Root growth index	Root depth (cm)	Root moisture content (%)	Root surface area (cm ²)	Root volume (cm ³)	Cumulative length of roots (cm)	Biomass of roots (g)
	45±15	62.33±8.95	162.64±24.53	4.88±0.69	464.12±78.82	4.43±0.58

1.2.2 Determination of photosynthetic parameters

The net photosynthetic rate (Pn, $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) and transpiration rate (Tr, $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) of labeled leaves of *Artemisia ordosica* were measured at 10:00 a.m. to 11:00 a.m. using a Li-6800 (Li-Cor, USA) portable photosynthesis measurement system, and three leaves of each plant were selected for measurement. The instantaneous water use efficiency ($\mu\text{mol}\cdot\text{mmol}^{-1}$) of *Artemisia ordosica* leaves was calculated using the formula $\text{WUE}=\text{Pn}/\text{Tr}$.

1.3 Data processing

The data were processed and plotted using Excel and Sigma Plot 14.0 software, and statistical tests were performed using SPSS 20.0 software. The Least Significant Difference (LSD) method was selected to test the differences in photosynthetic characteristics of *Artemisia ordosica* leaves under different degrees of damage, and the differences in tensile properties of single roots of *Artemisia ordosica* under single load, light cyclic load and heavy cyclic load were tested ($\alpha=0.05$).

2 Results and Analysis

2.1 Changes in photosynthetic properties of *Artemisia ordosica* leaves after root break

Root damage could significantly affect the changes of leaf net photosynthetic rate (Fig. 1a). During the study period, the mean net photosynthetic rate of *Artemisia ordosica* leaves differed significantly ($P<0.05$) with different root damage treatments, and the trend was that the greater the root damage, the lower the net photosynthetic rate of leaves, which showed that control ($28.63 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) > mild damage ($23.58 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) > moderate damage ($21.16 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) > severe damage ($16.57 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$). This inhibition of net photosynthetic rate by root damage will persist after the damage is formed, and this index is still on average 23.13% lower than the control after 75 d of damage. It indicates that the net

photosynthetic rate of leaves of *Artemisia ordosica* will be inhibited for a longer period of time after the root system is damaged by erosion, leading to a significant reduction in photosynthetic product conversion and accumulation.

Root damage significantly affected the changes in leaf transpiration rate (Fig. 1b). The mean transpiration rate of *Artemisia ordosica* leaves under different root damage treatments was significantly different ($P<0.05$) and showed a trend of decreasing transpiration rate with increasing damage, ranked as control ($0.011 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) > mild damage ($0.009 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) > moderate damage ($0.008 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) > severe damage ($0.005 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$). The negative feedback of root damage on leaf transpiration rate was not eliminated during the experiment, and the index was still reduced by an average of 9.36% compared to the control after 75 d of damage. It indicates that the root system of *Artemisia ordosica* is damaged by erosion and its own water transport function will be inhibited to some extent in the long term.

Root damage also significantly altered the water use efficiency of *Artemisia ordosica* leaves (Fig. 1c). The mean water use efficiency differed significantly ($P<0.05$) under different root damage treatments, and the greater the degree of root damage, the stronger the water use efficiency, as indicated by severe damage ($3.45 \mu\text{mol}\cdot\text{mmol}^{-1}$) > moderate damage ($2.75 \mu\text{mol}\cdot\text{mmol}^{-1}$) > mild damage ($2.62 \mu\text{mol}\cdot\text{mmol}^{-1}$) > control ($2.48 \mu\text{mol}\cdot\text{mmol}^{-1}$). The effect of the degree of root damage of *Artemisia ordosica* was most obvious at the early stage of damage (1-6 d), and the water use efficiency after severe damage was 42.82%, 40.88% and 38.95% higher than that of the control, light and moderate damage, respectively, indicating that *Artemisia ordosica* is highly adaptable to the limiting environment, responds very quickly to erosion stress, and can continuously adjust its survival strategy with the increase of the stress level.

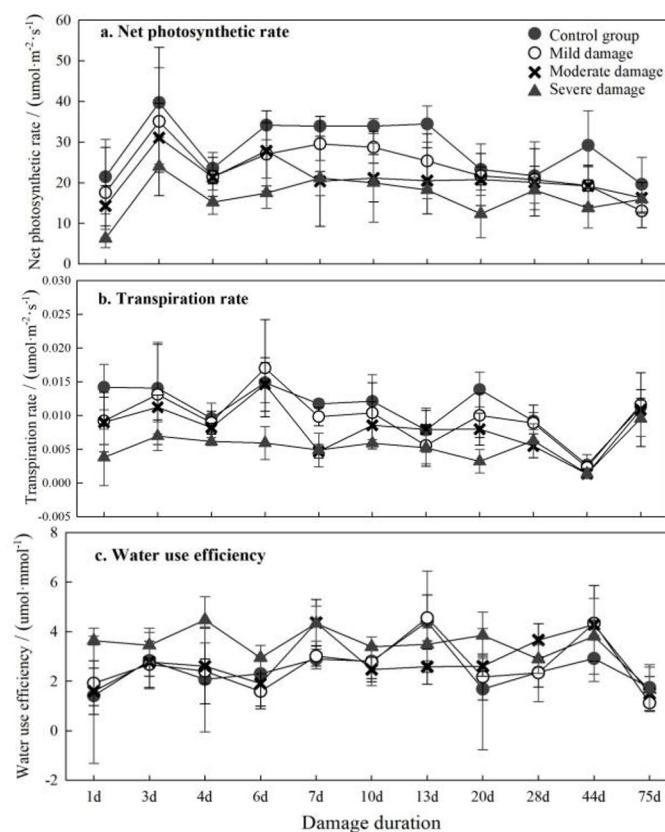


Fig.1 Variation of photosynthetic characteristics of *Artemisia ordosica* leaves after root damage

2.2 Changes in growth characteristics of *Artemisia ordosica* after root breakage

As shown in Fig. 2, the changes in the growth status of above-ground branches and leaves of *Artemisia ordosica* after 75 d of different degrees of root damage were significantly different ($P < 0.05$). The growth rates of plant height, crown width, branch length and diameter were all positive, indicating that *Artemisia ordosica* could still grow after root damage, but the growth rates of all indicators after damage were significantly lower than those of the undamaged control, indicating that root damage had an inhibitory effect on plant growth, and the

growth rates of all indicators were: control > mild damage > moderate damage > severe damage, indicating that the greater the degree of damage, the more significant the inhibitory effect on growth. The growth rate of each index showed: control > light damage > moderate damage > heavy damage, indicating that the greater the degree of damage, the more significant the growth inhibition. Under severe damage to the whole root system, the growth rate of height, crown width, branch length, and branch diameter decreased by 38.91%, 42.61%, 68.11%, and 65.84%, respectively, compared with the control, while the growth indexes of the whole root system only decreased by 8.27%, 2.32%, 23.06%, and 25.77%, respectively, under light damage.

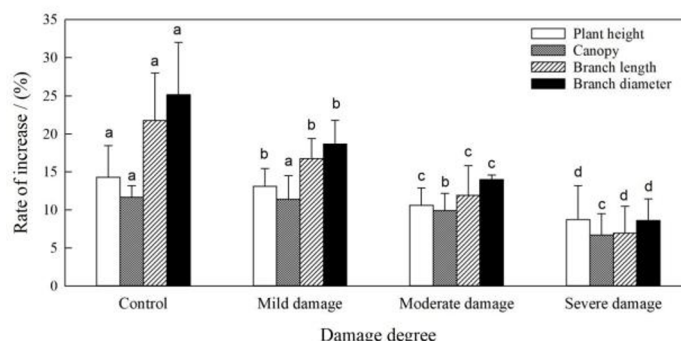


Fig.2 Variation of growth characteristics of *Artemisia ordosica* after root damage

Note: Different lowercase letters indicate significant differences ($P < 0.05$) in the same growth index of *Artemisia ordosica* at different levels of damage.

3 Conclusion

Gravitational erosion in the form of ground fractures or

ground subsidence formed by coal mining in semi-arid mining areas is highly susceptible to fracture damage to the whole root system of *Artemisia ordosica* in the erosion zone. In the present study, mild, moderate and severe root

fracture damage from simulated erosion all produced significant and long-term inhibition of net photosynthetic rate and transpiration rate of *Artemisia ordosica* leaves, and had the variation characteristic that the greater the degree of root damage, the more obvious the index inhibition effect, which is consistent with the findings of Yao Dongdong et al.^[1] on northern salix. This is because the root system assumes the function of plant water and nutrient uptake and conduction, which in turn are factors that directly or indirectly affect the photosynthesis of plant leaves^[2], and the value of root system contribution to photosynthesis will be lost accordingly due to the degree of its disruption. The different degrees of root disconnection in *Artemisia ordosica* reduces the effective supply of water, which is used as a raw material for photosynthesis in plants, and the lack of raw material will directly reduce the net photosynthetic rate of leaves^[3]. At the same time, water deprivation leads to an increase in the amount of abscisic acid in the leaves, causing stomatal closure, reducing the amount of CO₂ entering the leaves, decreasing the intercellular CO₂ concentration, and indirectly weakening the net photosynthetic rate of the leaves^[4]. Nitrogen is one of the most important nutrients for plant photosynthesis, and leaf nitrogen content is positively correlated with photosynthetic rate, and root breakage reduced nitrogen uptake by *Artemisia ordosica* and thus reduced the net photosynthetic rate of leaves^[5]. Root break damage also significantly reduced the transpiration rate of *Artemisia ordosica* leaves, because 90% of water consumption for leaf transpiration comes from stem fluid flow, and root break caused a reduction in water transport in xylem conduits, which resulted in a limitation of transpiration rate after the reduction of stem fluid flow^[6].

The experimental results showed that root break damage increased the water use efficiency of *Artemisia ordosica* leaves, and the greater the degree of breakage, the higher the water use efficiency, indicating that *Artemisia ordosica* would improve water use efficiency under erosion stress by adjusting its own carbon-water synergistic relationship to achieve adaptation to adversity and maintain its own survival and growth^[7]. The study by Chen et al.^[8] also showed that changing water use efficiency is a reflection of plant ecological adaptations and survival instincts. Changes in soil water availability are the direct cause^[9]. On the one hand, erosion damage from coal mining exposes deep soil layers and accelerates evaporation of soil water from the profile thereby reducing soil water content^[10]; on the other hand, partial root breakage leads to reduced channels for water uptake by plants. Under the condition of reduced soil water availability, plants open water conservation strategies to maintain internal water balance and maximize water use efficiency by reducing water consumption^[11].

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