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Research Article

The Effect of Soil Moisture Content on the Growth and Photosynthetic Rate of *Quercus acutissima* Seedlings

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Abstract

With the increasing severity of global climate change, frequent meteorological droughts have caused changes in the water conditions of plant communities, limiting plant growth and leading to a decrease in plant productivity. In the process of vegetation restoration, the introduction of woody plants is constrained by soil moisture. While managing traditional forest nurturing measures, the study of plant functional traits can reflect the growth status of plants. Based on this, this study focuses on the commonly used tree species, *Quercus acutissima*, in the process of vegetation restoration in North China. Using greenhouse controlled experiments, the growth performance, biomass allocation, and leaf functional traits of seedlings under different water conditions were measured. The decrease in soil moisture inhibited the growth of *Q. acutissima* seedlings, resulting in a significant decrease in plant height, base diameter, crown width, and total biomass. The seedlings of *Q. acutissima* adjusted the biomass allocation of the whole plant and tissues within organs to adapt to water deficit. The increase in the proportion of root biomass and fine root biomass helps plants obtain more water. In order to reduce water loss, the stomata of the leaves are closed, which inhibits photosynthesis and leads to a decrease in organic matter accumulation. The LMA of seedlings is relatively stable, which may be a trade-off between light acquisition and water retention in plants.

Keywords

Quercus acutissima, Soil Moisture, Plant Functional Traits, Biomass Allocation

1. Introduction

1.1. Effects of Water Factors

Water is an essential resource for plant growth and plays a crucial role throughout the entire life cycle of plants [1]. It serves as the primary resource or medium involved in metabolic processes such as photosynthesis, nutrient transport, and transpiration. The acquisition, maintenance, and utilization of water by plants are of great significance for individual survival, inter species competition, and the composition of plant communities. In order to adapt to different climate and water conditions, plants have evolved different adaptation strategies, such as non equal water regulation behaviors, to achieve plant survival and distribution through a combina-

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tion of related traits.

With the increasing severity of global climate change, the original spatial and temporal patterns of precipitation have been altered, leading to frequent occurrence of extreme weather events. Frequent meteorological droughts cause changes in the water conditions of plant communities, and drought stress restricts the survival and growth of plants, leading to a decrease in plant productivity and profound impacts on the species composition and structure of plant communities [2]. In the process of vegetation restoration, the introduction of woody plants is constrained by site conditions, especially soil moisture, which greatly affects the survival rate and growth of seedlings.

1.2. Plant Functional Traits

Plant functional traits refer to the structural and physio-logical traits of plants that respond to environmental changes and have a certain impact on ecosystem functions [3, 4]. Plant functional traits emphasize the role of traits in a influencing the environment, and have stronger practical significance in research. Therefore, plant functional traits provide a good perspective for studying the relationship between plants and the environment [5]. In recent years, the study of plant functional traits has become a hot topic in research at various levels of plants, from individuals, communities to ecosystems. In 2004, 33 scientists including Lan J. Wright from the United States, Australia, and South Africa jointly published a research paper on the global leaf economic spectrum in Nature [6]. The relationship between plant leaf functional traits and environmental factors has been revealed for the first time at a global scale. In subsequent research, scientists have carried out effective work on plant functional traits. Reich expanded the original leaf economic spectrum to include the universal "fast slow" plant economic spectrum hypothesis of leaf stem root and carbon nutrient water through a review study [7]. Reich proposed that the dominant factor driving the biomass allocation pattern of forest plant organs such as leaves, stems, and roots at the global scale is temperature. Through meta-analysis, it was found that the leaf morpho-logical traits of over 800 plants in northern China are significantly influenced by water gradients and growing season temperatures [8]. The main functional traits of 386 perennial plants in Australia specific leaf area and leaf width significantly increase with the increase of soil moisture [9]. The functional traits of Cleistogenes squarrosa show a significant response to nitrogen addition, and the response pattern varies under different water conditions, reflecting its elastic adaptation to changes in nitrogen water environment [10].

While managing traditional forest nurturing measures, the study of plant functional traits can reflect the growth status of plants. At the same time, the study has certain guiding significance for screening afforestation plants and formulating differentiated and precise forest management measures. Based on this, this study focuses on the commonly used tree species, *Quercus acutissima*, in the process of vegetation restoration in North China. Using greenhouse controlled experiments, the growth performance, biomass allocation, and leaf functional traits of seedlings under different water conditions were measured. And propose the following hypothesis:

1) The decrease in soil moisture content will limit the growth of *Q. acutissima* seedlings.
2) *Q. acutissima* seedlings adapt to drought stress by adjusting biomass allocation and functional traits.

2. Materials and Methods

2.1. Experimental Materials and Design

The experiment uses actual oak seedlings, which are required to have normal growth and morphology, no pests and diseases, good growth conditions, and basically consistent growth. This experiment adopts a pot experiment and a random block experimental design. One *Quercus acutissima* seedling is planted in each pot. The experiment simulates different soil moisture conditions to study the effect of moisture conditions on the growth of *Q. acutissima* seedlings. The method of controlling moisture content is divided into five gradients, namely 85% -75%, 70% -60%, 55% -45%, 40% -30%, and 25% -15% of the saturated soil moisture content (referred to as treatment W1, W2, W3, W4, W5). Each of them handles five repetitions. Before the experiment begins, the soil is weighed, water is added, and the saturated moisture content is controlled to reach five moisture gradients. The experiment begins when the moisture content reaches five moisture gradients. After the experiment begins, the soil moisture content is measured every morning and the lost moisture from the previous day is replenished to maintain the set soil moisture gradient for each moisture treatment. The experimental processing will last for three months, and after three months, the experimental samples will be uniformly processed and measured.

2.2. Experimental Methods

The experimental treatment lasted for 3 months. At the end of the experiment, the plant samples were subjected to biomass harvesting treatment. Each part of the plant was dried and weighed separately, and the weights of the plant leaves, stems, lateral roots, and main roots were measured, and the proportion of each part in the biomass was calculated. Measure the plant height and basal diameter before harvesting biomass. Before the end of the experiment, select 3 to 4 plants from each treatment to measure the net photosynthetic rate. Before the end of the experiment, select 5 leaves from each plant, scan, weigh, and calculate the specific leaf weight of the leaves.

3. Results and Analysis

3.1. The Effect of Water on the Growth Performance of *Q. acutissima* Seedlings

In this study, water gradient had a significant impact on the growth performance of *Q. acutissima* seedlings (Table 1).

Table 1. *Results of one-way ANOVA for growth performance traits of Q. acutissima seedlings under different moisture gradients.*

Traits	F	p
Height	10.816	0.000
Base diamet	6.581	0.002
Crown width	5.034	0.006
Biomass	8.884	0.000

The plant height of *Q. acutissima* seedlings showed a significant decreasing trend with the decrease of soil moisture, reaching its lowest point at W5. The height of seedlings under W4 and W5 treatments was significantly lower than the other three water gradients (Table 2). The crown width and plant height of *Q. acutissima* seedlings showed similar results, with the lowest value observed at W5 and significantly lower than the W1, W2, and W3 treatments (Table 2). The basal diameter of *Q. acutissima* seedlings gradually decreases with decreasing water content, reaching its lowest point at W5 and significantly lower than the other four water gradients (Table 2).

Table 2. *Growth performance traits of Q. acutissima seedlings under different moisture gradients.*

moisture gradient	Height	moisture gradient	Height
W1	52.7±15.16 a	1274.8±735.62 a	7.476±1.44 a
W2	49.16±9.97 a	1062.3±521.66 ab	7.314±1.15 a
W3	41.94±10.77 a	641.79±225.65 ab	6.514±1.93 a
W4	27.3±5.19 b	424.65±108.39 b	5.532±1.02 a

Values are presented as mean ± SD.

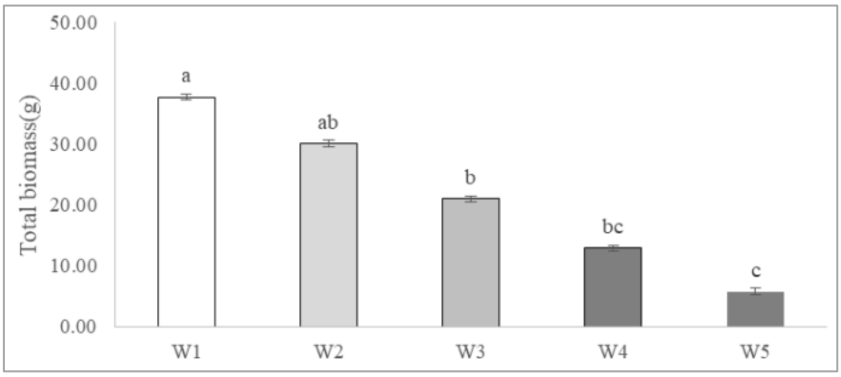

Figure 1. *Total biomass of Q. acutissima seedlings under different moisture gradients.*

In this study, under different treatments, the total biomass of *Q. acutissima* seedlings showed a decreasing trend with the decrease of water content. The total biomass of *Q. acutissima* seedlings was highest in the W1 treatment and significantly higher than in the W3, W4, and W5 treatments. The total biomass is the lowest in W5, with only 15.3% of the total biomass in W1 treatment. Significantly lower than W1, W2, and W3 treatments.

3.2. The Effect of Water on Biomass Allocation of *Q. acutissima* Seedlings

In this study, the effect of water gradient on the biomass allocation of *Q. acutissima* seedlings was relatively small, and leaf mass ratio (LMR), root lmass ratio (RMR), and root shoot ratio(RSR) were not significantly affected (Table 3).

With the decrease of soil moisture content, the LMR of *Q. acutissima* seedlings slightly decreased, and the LMR in W5 treatment decreased by 5.1% compared to W1 treatment. Correspondingly, as the soil moisture content decreases, *Q. acutissima* seedlings allocate more biomass to their roots and stems. The RMR in W5 treatment increased by 10.4% compared to W1 treatment. The RSR in W5 treatment showed a significant increase (25.9%) compared to W1 treatment, but the difference did not reach a significant level (Table 3).

Table 3. *Results of one-way ANOVA for biomass allocation of Q. acutissima seedlings under different moisture gradients.*

Traits	*F*	*p*
LMR	0.144	0.963
RMR	2.048	0.126
RSR	2.203	0.105
FMR	5.263	0.005

The water gradient has a significant impact on the biomass of different components in the roots of *Q. acutissima* seedlings. With the decrease of soil moisture, the biomass allocation of fine roots in *Q. acutissima* seedlings increased, and the fine root to main root ratio (FMR) significantly increased (Figure 2). FMR was highest in W5 treatment, significantly higher than W1 and W2 with higher soil moisture.

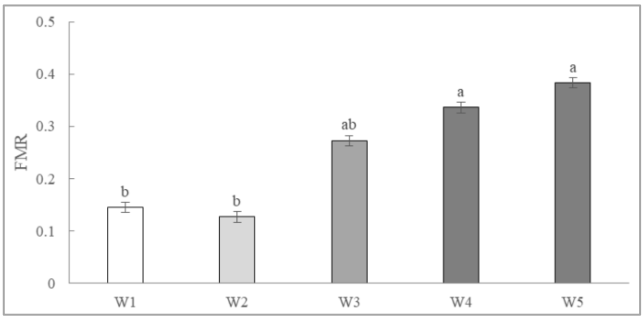

Figure 2. *FMR of Q. acutissima seedlings under different moisture gradients.*

3.3. The Effect of Water on Leaf Functional Traits of *Q.* Seedlings

In this study, water gradient did not have a significant effect on the net photosynthetic rate (p=0.200) and leaf mass per area (p=0.094) of the main functional traits of *Q. acutissima* seedlings. However, under different water content conditions, as the water content decreases, the net photosynthetic rate(A) of *Q. acutissima* seedlings still shows a decreasing trend. The lack of soil moisture reduces the A of *Q. acutissima* seedlings. In the W5 treatment, the net photosynthetic rate was the lowest, and only 57.7% of that in the W1 treatment.

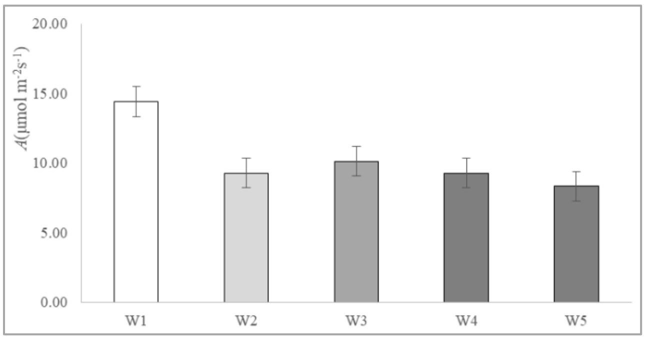

Figure 3. *A of Q. acutissima seedlings under different moisture gradients.*

In this study, under different water content conditions, the leaf mass per area(LMA) of *Q. acutissima* seedlings showed a relatively stable trend, with small differences between treatments.

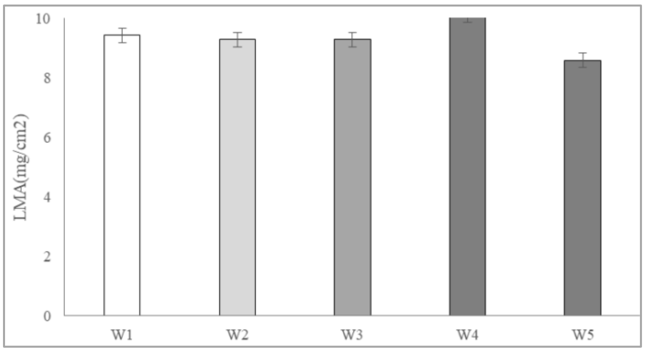

Figure 4. *LMA of Q. acutissima seedlings under different moisture gradients. Values are presented as mean ± SE. Different letters denote significant differences at p < 0.05 by Duncan`s test.*

4. Discussion

Water, as an essential resource for plant growth, is crucial for individual development and metabolism [2, 11]. The decrease in soil moisture significantly inhibited the growth of *Q. acutissima* seedlings. As soil moisture decreases, plant height, base diameter, crown width, and total biomass all significantly decrease. This is consistent with our first hypothesis. The adjustment of biomass allocation is an important mechanism for plants to adapt to environmental stress. Under drought conditions, plants often allocate more biomass to their roots to improve their ability to obtain water [12, 13]. In this study, with the decrease of soil moisture, the root mass ratio and root to shoot ratio of *Q. acutissima* seedlings showed a significant increase. At the same time, the fine root to main root ratio significantly increased, which helped the root system to diffuse and obtain water in the soil. The reduction in biomass allocation of aboveground leaves and stems helps plants reduce transpiration and decrease water loss. This is also consistent with our second hypothesis [13].

Leaves are the main organs for photosynthesis and transpiration in plants, and they are the most sensitive organs to environmental changes. The functional traits of leaves can reflect the ability of plants to adapt to changes in soil moisture. In this study, as soil moisture decreased, the net photosynthetic rate of *Q. acutissima* seedlings' leaves showed a decreasing trend. Insufficient water can lead to a decrease in plant photosynthesis, which in turn affects plant growth and the accumulation of organic matter [14]. The leaf mass per area reflects the organic matter allocation strategy during plant leaf construction and is an important trait reflecting the acquisition of plant light resources. In this study, there was no significant difference in LMA of *Q. acutissima* seedlings among different treatments, showing a relatively stable state. This may be due to water deficit limiting the increase in leaf area, as the LMA of *Q. acutissima* seedlings did not show significant changes in the balance between light acquisition and water limitation. This is inconsistent with our second hypothesis, but not with Zhou Jie. The results of et al's research on the adaptation strategies of *Alhagi sparsifolia* to drought are similar [15].

5. Conclusions

This experiment simulated different soil moisture gradients in a greenhouse to study the effects of moisture on the growth of *Q. acutissima* seedlings and their adaptation strategies. The decrease in soil moisture inhibited the growth of *Q. acutissima* seedlings, resulting in a significant decrease in plant height, base diameter, crown width, and total biomass. The seedlings of *Q. acutissima* adjusted the biomass allocation of the whole plant and tissues within organs to adapt to water deficit. The increase in the proportion of root biomass and fine root biomass helps plants obtain more water. In order to reduce water loss, the stomata of the leaves are closed, which inhibits photosynthesis and leads to a decrease in organic matter accumulation. The LMA of seedlings is relatively stable, which may be a trade-off between light acquisition and water retention in plants. Further research will focus on the effect mechanism of soil moisture content on the growth and photosynthetic rate of *Quercus acutissima* seedlings.

Abbreviations

LMR	Leaf Mass Ratio
RMR	Root Mass Ratio
RSR	Root to Shoot Ratio
FMR	Fine Root to Main Root Ratio
LMA	Leaf Mass Per Area
A	Net Photosynthesis Rate

Author Contributions

Yujie Luo: Conceptualization
Jin Dong: Funding acquisition
An Mao: Formal Analysis
Yifu Yuan: Methodology, Writing – original draft

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Conflicts of Interest

The authors declare no conflicts of interest.

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