Postprint: Biomass and Root Distribution Characteristics of *Artemisia sphaerocephala* in Semi-arid Sandy Lands

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Abstract

Artemisia sphaerocephala is the dominant sand-fixing species in the semi-arid regions of northwestern China. Its root system distribution significantly influences vadose zone water transport processes, making accurate characterization of vegetation traits and root density distribution essential for developing root water uptake models. This study employed the monolith method to obtain root samples and rhizosphere soil moisture content from different soil depths, and introduced crown class and age class concepts to investigate the root distribution characteristics of Artemisia sphaerocephala. The results demonstrate that: the Artemisia sphaerocephala population is dominated by young age-class individuals, with root biomass exhibiting sigmoidal growth patterns across age classes; both root length distribution and normalized root density distribution follow lognormal distributions, peaking in the shallow soil layer at 20 cm depth; Artemisia sphaerocephala growth is independent of groundwater, with its root system primarily utilizing vadose zone water. Under sustained drought conditions, the root system employs two adaptive strategies to meet transpiration demands: (1) increasing root mass through lateral growth to exploit water from the lateral soil profile; (2) compensating for reduced water uptake in shallow root zones due to water stress through enhanced uptake from deeper, relatively moist root zones. Consequently, the root density distribution function in Artemisia sphaerocephala root water uptake models should adopt a lognormal distribution, and the water uptake process depends on both root density distribution and soil moisture conditions.

Full Text

Preamble

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3. Methodology

3.1 Study Area Description

The study area is located at the Shapotou ecological research station on the southeastern edge of the Tengger Desert, at the border between Ningxia Hui Autonomous Region and Inner Mongolia Autonomous Region. This region has a typical semi-arid continental monsoon climate with an average annual precipitation of 200–400 mm, concentrated primarily in July through September. The landscape consists of mobile and semi-mobile sand dunes. The main vegetation species include *Artemisia ordosica*, *Salix cheilonhila*, *Caragana microphylla*, and *Caragana intermedia*. The study area is dominated by *Artemisia ordosica* communities, which cover approximately 86.83% of the region, totaling about 3.0×10 hm^2. The soil is classified as sandy soil with minimal clay content.

[Figure 1: see original paper]

3.2 Data Collection

In August 2016, we conducted whole-plant excavation of *Artemisia ordosica* individuals. The sampling process involved: (1) selecting representative sample plots, (2) choosing healthy, typical *Artemisia ordosica* plants, and (3) excavating the complete root systems. We used a Mini-Diver water level recorder to measure soil moisture content at different depths. The soil moisture content was calculated using the formula:

$$Y = a + b \cdot X^c$$

where Y represents soil moisture content, X represents depth, and a, b, and c are fitted parameters. Based on field measurements, the specific formula was determined to be:

$$Y = 1.013 \cdot X^{1.144} - 1.996, \quad R^2 = 0.9515$$

Root systems were classified into five diameter classes according to international standards [25]: fine roots ($\Phi < 1$ mm), small roots (1 mm $\Phi < 2$ mm), medium roots (2 mm $\Phi < 5$ mm), large roots (5 mm $\Phi < 10$ mm), and coarse roots (Φ 10 mm). Root biomass was measured using the washing method, and soil moisture content was determined using the oven-drying method.

3.3 Data Analysis

Root biomass distribution and rhizosphere soil moisture content were analyzed using statistical methods. The relationship between root distribution and soil moisture was examined at both the individual plant level and the community level. The analysis focused on: (1) vertical distribution patterns of root biomass, (2) horizontal distribution characteristics, and (3) the relationship between root density and soil moisture content. Statistical significance was tested at $p < 0.05$ level.

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4. Results and Discussion

The root system distribution of *Artemisia ordosica* follows a lognormal distribution pattern. The uniform root density distribution model not only ignores individual differences among *Artemisia ordosica* plants but also lacks universal applicability. Under persistent drought conditions, reduced water uptake in shallow root zones due to water stress can be compensated by increased water uptake in deeper, relatively moist root zones. This compensation mechanism demonstrates that root water uptake is not solely dependent on root system density distribution but also on the water status of the vadose zone.

The study reveals that root biomass distribution exhibits significant spatial heterogeneity. In the 0-50 cm soil layer, root biomass accounts for 80-90% of the total root biomass, while below 50 cm, the proportion decreases to 40-50%. This distribution pattern reflects the plant' s adaptive strategy to arid environments, where intensive root development in surface soil layers maximizes capture of scarce precipitation.

[Figure 2: see original paper]

The relationship between root density and soil moisture content can be expressed as:

$$\theta(z,t) = S(z,t) \cdot \alpha(\psi) \cdot \beta(T)$$

where $\theta(z,t)$ is the soil moisture content at depth z and time t, $S(z,t)$ represents the root density distribution function, $\alpha(\psi)$ is the soil water potential function, and $\beta(T)$ is the temperature influence function.

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Abstract: The characteristics of root system distribution play a crucial role in root water uptake simulation and the flow dynamics in vadose zones with vegetation in semi-arid regions. Linear and simple nonlinear root density distribution models were frequently adopted in previous research, and most root water uptake models depended on the root system density distribution closely. In order to depict the real *Artemisia ordosica* root system density distribution and its relationship with soil water content, the root biomass and rhizosphere soil moisture were obtained by mining *Artemisia ordosica* roots integrally and were analyzed using the concept of plant crown level and static age level in this study. The results indicated that the *Artemisia ordosica* root system is in accordance with lognormal distribution, and the uniform root density distribution cannot only ignore the difference among *Artemisia ordosica* individuals, but also is of universal applicability. When there is a persistent drought, the reduced root water uptake in shallow root zone by water stress could be compensated by the root water uptake in deep root zone where it is relatively moist. Therefore, the complex biophysics indicates that the root water uptake is not only related to the root system density distribution, but also depends on the water state in vadose zone.

Keywords: semi-arid region; *Artemisia ordosica*; age class; distribution of root system

Note: Figure translations are in progress. See original paper for figures.