Postprint: Ecological Characteristics of Reed Populations in the Sandy Land on the Southern Margin of the Badain Jaran Desert

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Abstract

Investigations were conducted on the modular characteristics, population age structure, dynamic features, and spatial distribution patterns of ramet populations of *Phragmites australis* naturally distributed in two sandy habitats (saline sandy land and ordinary sandy land) on the southern margin of the Badain Jaran Desert. The research indicates that: (1) Both soil water content and salinity in saline sandy land were significantly higher than those in ordinary sandy land; plant height, total biomass, and biomass of each module of *P. australis* in ordinary sandy land were generally higher than those in saline sandy land; soil water content and salinity are important driving factors for the morphological characteristic differences of *P. australis* in this region. (2) Due to differences in soil conditions and interspecific competition intensity among different habitat plots, *P. australis* populations exhibited different age structures and quantitative dynamic changes; the *P. australis* population in ordinary sandy land tended to be declining, while that in saline sandy land showed a growth trend. (3) The spatial distribution pattern of *P. australis* populations in ordinary sandy land exhibited clumped distribution at scales of 0–4 m and random distribution at scales greater than 4 m; the function values in saline sandy land were basically between the two envelope lines, showing random distribution within the scale range of 0–10 m.

Full Text

Population Ecological Features of *Phragmites australis* in Sandy Habitats on the Southern Edge of the Badain Jaran Desert

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Abstract

The modular characteristics, population age structure, dynamic features, and spatial distribution patterns of *Phragmites australis* ramet populations were investigated in two types of sandy habitats (saline sandy land and common sandy land) naturally distributed on the southern margin of the Badain Jaran Desert. The results demonstrated that: (1) Soil water content and salinity in saline sandy land were significantly greater than those in common sandy land. The plant height, biomass, and component biomass of *P. australis* in common sandy land were generally higher than those in saline sandy land, indicating that soil water and salt content are important driving factors for morphological differences in *P. australis* in this region. (2) Due to variations in soil conditions and interspecific competition intensity among different habitats, *P. australis* populations exhibited distinct age structures and quantitative dynamics. The population in common sandy land tended toward a declining type, whereas the population in saline sandy land showed an increasing trend. (3) The spatial distribution pattern of *P. australis* populations in common sandy land was aggregated at scales of 0–4 m and random at scales greater than 4 m. In saline sandy land, the K-function values generally fell between the two envelope traces, showing random distribution at scales of 0–4 m and random distribution across all scales from 0 to 10 m.

Keywords: Badain Jaran Desert; sandy land; *Phragmites australis* population; modular characteristics; age structure; quantitative dynamics; spatial distribution pattern

Introduction

The southern margin of the Badain Jaran Desert, located in the central-northern part of the Hexi Corridor, represents the frontier of interaction between oasis and desert ecosystems and is therefore termed the oasis-desert ecotone. The growth status and population dynamics of vegetation in this transition zone determine the retreat or expansion of oases. Under inland desert climate conditions, soil moisture and salinity conditions are the primary driving factors affecting the stability of the ecotone and vegetation changes. Over recent decades, driven by both human activities and regional climate change, the groundwater level in this area has declined year by year, soil aridification and salinization have intensified, and vegetation growth has been restricted. This situation urgently requires strengthened vegetation protection efforts to maintain ecological security.

Phragmites australis is a widely distributed perennial grass species of the genus *Phragmites*, with typical habitats along rivers, lakesides, and marshes. Due to its strong adaptability, *P. australis* can survive and form different ecotypes even under poor environmental conditions. Naturally growing *P. australis* is one of the dominant species in the study area. As a typical clonal plant, *P. australis* has strong sprouting ability, and its clone system connected by numerous rhizomes increases surface roughness, reduces wind-sand hazards, fixes drifting sand, effectively curbs desert expansion, protects oases, and facilitates vegetation restoration and reconstruction, giving it important ecological status in the oasis-desert ecotone of the Hexi Corridor.

Previous research on *P. australis* has mainly focused on aquatic reeds in humid and semi-humid regions, with numerous studies on reeds in arid areas in recent years. However, reports on the population ecology of psammophytic reeds remain rare. This study investigates naturally distributed *P. australis* populations in saline sandy and common sandy habitats on the southern margin of the Badain Jaran Desert, analyzing their growth characteristics, population dynamics, and spatial distribution patterns to reveal the survival status and population quantitative dynamic patterns of reeds in the oasis-desert ecotone, thereby providing theoretical support for vegetation protection, environmental management, and ecosystem stability in this region.

1. Materials and Methods

1.1 Study Area Overview

The survey plots were established in sandy land at Guazhai Village, Yannuan Town, Linze County, Zhangye City, located on the southern margin of the Badain Jaran Desert (99°51 -100°30 E, 38°57 -38°85 N). The two habitat plots are distributed within the same geographic coordinates and are therefore considered to have identical climatic conditions, both characterized by typical arid desert climate. Annual precipitation is 118 mm, mainly distributed from June to September, with annual evaporation of 2238 mm. Wind-sand is strong, water distribution is extremely uneven, soil desertification and secondary salinization are serious, and plant growth environments are harsh. *Phragmites australis* is the dominant species in this area, with main associated species including *Haloxylon ammodendron*, *Peganum harmala*, and *Tamarix chinensis*. The reeds in this area originated from marsh habitats along the Heihe River banks, and during long-term adaptation to salinized soil and dune habitats, their morphological structures have undergone significant changes adapted to specific environments.

1.2 Sample Plot Setup

In late August, after thorough reconnaissance, relatively concentrated *P. australis* distribution areas were selected in both saline sandy land and common sandy land habitats. In each habitat, three 20 m × 20 m sample plots were established using a "Z" pattern. In each plot, 30 reproductive ramets of *P.*

australis were randomly selected and cut at ground level. Each habitat yielded 90 samples for measurement of ramet height, base diameter, and inflorescence length, after which samples were taken back to the laboratory.

For investigating the spatial distribution pattern of *P. australis* ramet populations, the adjacent grid method was used. Three sample plots were randomly selected in each habitat, and each 20 m × 20 m plot was divided into 1 m × 1 m subplots. Using the southwest corner of each subplot as the origin, the two-dimensional spatial position of each *P. australis* plant relative to the origin was measured and recorded.

1.3 Ramet Component Biomass Measurement

Each *P. australis* plant was separated into component parts (stem, leaf, leaf sheath, and inflorescence), which were placed in labeled aluminum foil packets and dried in an oven at 80°C for 48 hours. An analytical balance was used to weigh the dry mass of stems, leaves, leaf sheaths, and inflorescences. The sum of component dry masses was calculated as aboveground biomass.

1.4 Population Age Structure and Life Table Analysis

1.4.1 Population Age Structure and Static Life Table Population age structure is crucial for population dynamics research. While diameter at breast height or plant height are commonly used for woody plants, these methods are unsuitable for perennial clonal herbs like *P. australis*. Following Jiao Dezhi et al., this study used the number of leaves on base plants to determine age classes, with 2 leaves as the basic age class (I level) and increments of 2 leaves for each subsequent level, totaling 8 age classes. The number of plants in each age class was counted in sample plots, and population age structure diagrams were plotted with age class representing relative age on the vertical axis and number of individuals in each age class on the horizontal axis.

The static life table was constructed using the "space-for-time" substitution method to analyze population dynamics. Parameters in the life table and their meanings follow those detailed in the literature. The four survival functions introduced in survival analysis were used to further analyze population quantitative dynamics in the two sandy habitats and elucidate survival patterns.

1.4.2 Survival and Mortality Curves With age class as the horizontal coordinate and mortality rate and standardized survival number from the static life table as vertical coordinates, mortality curves and survival curves for *P. australis* populations were plotted.

1.4.3 Survival Analysis Four survival analysis functions were calculated:

- **Survival function**: $S(t_x) = \prod_{i=1}^{x-1} S_i$ (for $x = 1, 2, 3, 4, \cdots, n$)
- **Cumulative mortality function**: $F(t_x) = 1 - S(t_x)$

- **Mortality density function**: $f(t_x) = \frac{S_{x-1} - S_x}{h_x}$
- **Hazard rate function**: $\lambda(t_x) = \frac{2(1 - S_x)}{h_x(1 + S_x)}$

Where S_x is survival rate and h_x is interval length (age class width). Corresponding curves were plotted based on calculated function values.

1.4.4 Spatial Point Pattern Analysis Ripley' s K function was used to analyze population spatial patterns. The function equation is:

$$K(d) = \frac{A}{n^2} \sum_{i \neq j} \frac{I_d(u_{ij})}{w_{ij}}$$

Where A is sample plot area, n is number of individuals, d is distance scale, u_{ij} is distance between points i and j, I_d is an indicator function (equal to 1 when $u_{ij} \leq d$, otherwise 0), and w_{ij} is a weight for edge correction. Spatial patterns often show different distribution types at different scales.

1.5 Soil Factor Measurements

Since *P. australis* roots are mainly distributed within the 0–40 cm soil layer, soil samples were taken from each habitat plot at 20 cm intervals (0–20 cm and 20–40 cm) with three replicates, mixed evenly, and taken back to the laboratory. Soil water content was determined by the drying method, salt content by the mass method, and organic matter content by the potassium dichromate heating method.

1.6 Data Processing

Data collation and processing were performed in Excel 2010 and SPSS 26.0 using one-way ANOVA. Point pattern analysis was conducted using Programita (Wiegand edition) software, with figures prepared using Origin software.

2. Results

2.1 Soil Factors in Different Sandy Habitats

Significant differences were observed in soil water content and salt content between the two sandy habitats ($P < 0.05$). Both water and salt content decreased from saline sandy land to common sandy land, while organic matter content showed no significant difference between habitats and was less than 1 $g \cdot kg^{-1}$ (Table 1).

Table 1 Soil factors in two habitats

Habitat	Soil water content (%)	Soil salt content (g · kg^{-1})	Soil organic matter (g · kg^{-1})	pH
Saline sandy land	16.02±0.83a	2.13±0.33a	0.73±0.02a	8.66±0.08a
Common sandy land	9.15±0.77b	0.70±0.06b	0.69±0	

Note: Different lowercase letters in the same column indicate significant differences between plots ($P < 0.05$). The same below.

2.2 Ramet Component Characteristics and Biomass

The height, base diameter, and inflorescence length of *P. australis* in saline sandy land were significantly smaller than those in common sandy land, while tiller number was greater in saline sandy land (Table 2). This indicates that higher soil salinity inhibited growth while promoting more tillers. Leaf, stem, inflorescence, and aboveground biomass in saline sandy land were significantly lower than in common sandy land, with aboveground biomass in saline habitat accounting for only 60.55% of that in common sandy land. Leaf sheath biomass showed no significant difference between habitats, though values were higher in saline sandy land (Table 3).

Table 2 Component characteristics of *Phragmites australis* ramets in two habitats

Habitat	Height (cm)	Base diameter (mm)	Inflorescence length (cm)	Tiller number
Saline sandy land	63.33±18.06b	2.70±1.21b	14.30±7.65b	7.54±3.56a
Common sandy land	115.12±47.4a	4.90±3.96a	2	

Table 3 Aboveground biomass of *Phragmites australis* ramets in two habitats (g)

Habitat	Leaf biomass	Stem biomass	Leaf sheath biomass	Inflorescence biomass	Aboveground biomass
Saline sandy land	1.43±0.17a	1.85±0.21b	1.06±0.25a	0.84±0.03b	6.2±3.11b
Common sandy land	2.46±0.44a	5.28±0.32			

2.3 Population Age Structure and Dynamics

2.3.1 Age Structure and Static Life Table Analysis Based on counts of *P. australis* individuals in each age class, age structure diagrams were plotted for different habitats (Fig. 2). The saline sandy land plot contained 1,368 ramets, with individuals having 12–14 leaves accounting for 49.86% of the total population. The age structure showed a pyramid shape, typical of an increasing population, indicating that *P. australis* can adapt well to these conditions and maintain stable development. The common sandy land plot contained 1,062 ramets, with a spindle-shaped age structure (large middle and small ends), indicating that middle-aged individuals dominated while seedlings were scarce. This population is currently stable but may become declining because seedling growth cannot balance the senescence of adult plants.

Table 4 Static life table of *Phragmites australis* population in two habitats

Age class (x)	Saline sandy land									Common sandy land							
	a_x	l_x	d_x	q_x	L_x	T_x	e_x	S_x	K_x	a_x	l_x	d_x	q_x	L_x	T_x	e_x	S_x
I	682	1000	294	0.294	853	2100	2.100	0.706	0.346	53	1000	-377	-0.377	688	1863	1.863	1.377
II	482	706	118	0.167	647	1247	1.767	0.833	0.182	73	1377	-411	-0.298	1082	1175	0.853	1.298
III	402	588	147	0.250	515	600	1.020	0.750	0.288	103	1788	-534	-0.298	1382	93	0.052	1.298
IV	301	441	162	0.368	360	85	0.193	0.632	0.459	134	2322	1162	0.500	1741	-1289	-0.555	0.500
V	190	279	118	0.423	220	-275	-0.985	0.577	0.545	67	1160	313	0.270	1004	-3030	-2.613	0.730
VI	110	161	81	0.503	121	-495	-3.074	0.500	0.693	49	849	358	0.422	670	-4034	-4.752	0.578
VII	55	81	41	0.506	60	-555	-6.852	0.500	0.693	28	491	302	0.615	340	-4704	-9.580	0.385
VIII	27	40	—	—	—	—	—	—	—	11	189	—	—	—	—	—	—

Note: x = age class, a_x = number of individuals in age class x, l_x = standardized number of survivors, d_x = standardized number of deaths, q_x = mortality rate, L_x = number of individuals alive during age interval x, T_x = total number of individuals in age class x, e_x = life expectancy of individuals entering age class x, S_x = survival rate, K_x = killing power. The same below.

2.3.3 Survival Analysis Based on calculated survival function values, survival rate curves, cumulative mortality curves, mortality density curves, and hazard rate curves were plotted (Figs. 3-5). The survival number of *P. australis* in saline sandy land showed a gradually decreasing trend with age class, indicating that population survival decreased with age. In common sandy land, survival number initially increased then decreased, reaching a maximum at age class III. Mortality rates in both habitats peaked at age class I, indicating strong interference during transition from age class I to II. Life expectancy (e_x) showed a declining trend in both habitats, consistent with biological characteristics as populations approach physiological longevity.

The survival rate of *P. australis* populations in saline sandy land gradually decreased with age class, while cumulative mortality increased complementarily. The mortality density curve increased initially then remained stable, and the hazard rate curve increased gradually. In common sandy land, the survival rate increased initially, reaching a maximum at age class III before decreasing, with complementary cumulative mortality. The mortality density curve increased slowly, and the hazard rate curve decreased initially then increased. Combined analysis of the four survival functions revealed that the saline sandy land population showed overall stable development, while the common sandy land population was stable in early and middle stages but declined in later stages. Scientific protection and tending could restore population growth within a certain timeframe.

2.4 Spatial Distribution Patterns in Two Sandy Habitats

Spatial distribution scatter plots (Fig. 6) showed that *P. australis* individuals were far more densely distributed in saline sandy land than in common sandy land, with random distribution dominant in saline sandy land and aggregated distribution dominant in common sandy land. Point pattern analysis using Programita (Wiegand edition) software generated the results shown in Fig. 7. In common sandy land, the K function values were above the upper envelope at 0–4 m scales and within the envelope at scales >4 m, indicating aggregated distribution at 0–4 m scales and random distribution at larger scales. In saline sandy land, K function values were generally within the envelope traces, showing random distribution across all scales from 0 to 10 m.

3. Discussion

Phragmites australis distributed on the southern margin of the Badain Jaran Desert is affected by the interactive influences of drought and salinity. The ability of reeds to absorb nutrients changes under different salinity irrigation levels, and plant height, stem diameter, and biomass all decrease with increasing salinity. These results are consistent with Saydigul Haxim' s research on *P. australis* in the Keriya Oasis, which found that reed ecological indicators were affected by soil salt content to varying degrees. Tiller number was greater in saline sandy land, reflecting that under severe saline-alkali stress, reed growth is inhibited, leading to more lateral tillers to maintain its position in the community. The different quantitative characteristics of lateral tillers in the two habitats indicate that when habitats change, *P. australis* populations can adjust tiller structure and number to ensure adequate fitness.

Studying population structure and life table characteristics is important for deeply analyzing population status, dynamics, and future predictions. The population structure in saline sandy land showed an increasing type. Although seedling mortality was high, the large base number was sufficient to maintain seedling renewal. Plant populations lacking seedlings are generally considered declining; the common sandy land population had few seedlings and a spindle-shaped age structure with more middle-aged and adult individuals, indicating a stable-to-declining population type consistent with survival analysis results. Mortality curves, survival curves, and survival analysis can intuitively describe population status and reveal adaptation mechanisms between populations and environments. The saline sandy land population showed decreasing survival and increasing mortality, but survival analysis indicated a stable type, consistent with population structure analysis. The fundamental reason was the large number of seedlings and relatively low disturbance. The common sandy land population showed increasing survival in early stages, but low growth potential combined with survival analysis indicated a stable type following early-stage decline. Although plant populations have unique renewal methods, environmental changes affect individual numbers in specific age classes, causing age structure to deviate from its original shape and influencing natural regeneration.

Population spatial distribution patterns are formed through long-term interactions between plants and between plants and their environment, holding important ecological significance. *Phragmites australis* populations can adapt to heterogeneous environments through changes in spatial distribution patterns. Transitioning from common sandy land to saline sandy land with increasing environmental stress, the distribution pattern shifted from aggregated distribution supplemented by uniform and random distributions to random distribution supplemented by uniform and aggregated distributions. This pattern ensures that under favorable conditions, the population can occupy larger horizontal space and reduce intraspecific competition, while under harsh conditions, it can successfully "escape" unfavorable patches to improve survival fitness, reflecting the ecological adaptation strategy of *P. australis* populations developing toward more favorable expansion and reproduction under heterogeneous conditions.

4. Conclusion

Based on the natural distribution of *Phragmites australis* on the southern margin of the Badain Jaran Desert, this study investigated populations in common sandy land and saline sandy land as the dominant species. The main conclusions are:

1. Under two different sandy habitats, *P. australis* exhibited significant differences in ramet configuration, morphological characteristics of resource absorption organs, and aboveground biomass allocation through ecological plasticity to maximize environmental resource utilization.
2. The common sandy land *P. australis* population lacked seedlings and faced high risk of declining succession. Therefore, improving survival environments, protecting existing plants, and promoting seedling establishment

and survival are key to population restoration and growth.

3. *Phragmites australis* populations showed markedly different spatial distribution patterns between habitats, representing the result of habitat heterogeneity, regeneration limitation, and ecological adaptation.
4. Soil moisture and salt content are important driving factors causing differences in ramet modular characteristics, dynamic features, and spatial distribution patterns of *P. australis* populations between the two sandy habitats.

References

[1] Zhou Xiawei. The Study of the Sustainability of National Desertified Land Sealed Protection Policy[D]. Lanzhou: Lanzhou University, 2018.

[2] Ding Junxiang, Zou Jie, Tang Lisong, et al. Photosynthesis and physiological-biochemical characteristics of *Phragmites australis* in swamp, light salt meadow, and sand dune habitats[J]. *Acta Ecologica Sinica*, 2015, 35(16): 5316-5323.

[3] Liu Lele. Genetic Diversity, Phylogeography and Ecological Adaptation of *Phragmites australis*[D]. Jinan: Shandong University, 2020.

[4] Kirk H, Paul J, Straka J, et al. Long distance dispersal and high genetic diversity are implicated in the invasive spread of the common reed, *Phragmites australis* (Poaceae) in northeastern North America[J]. *American Journal of Botany*, 2011, 98(7): 1180-1190.

[5] Qiao Bin, He Tonghui, Yu Ji, et al. Growth of *Phragmites australis* population under different water depth gradients in lake wetland of the Yinchuan Plain[J]. *Arid Zone Research*, 2017, 34(4): 762-769.

[6] Jiao Dezhi, Yan Qiuyue, Jiang Qiuxu, et al. Quantitative characteristics and interrelation of module of *Phragmites australis* population in Zhalong Wetland[J]. *Chinese Journal of Ecology*, 2018, 37(7): 1983-1989.

[7] Hansen D, Lambertini C, Jampeetong A, et al. Clone specific differences in *Phragmites australis*: Effects of ploidy level and geographic origin[J]. *Aquatic Botany*, 2007, 86(3): 269-279.

[8] Yang Yunfei, Li Jiandong. Biomass allocation and growth analysis on the ramets of *Phragmites communis* populations in different habitats in the Songnen Plains of China[J]. *Chinese Journal of Applied Ecology*, 2003, 14(1): 30-34.

[9] Lin Wenfang, Chen Linjiao, Zhu Xueyi. An analysis of genetic diversity of different ecotypes of reed (*Phragmites australis* Trin.) by molecular marker techniques[J]. *Journal of Plant Physiology and Molecular Biology*, 2007, 33(1): 77-84.

[10] Jiao Dezhi, Huang Zhaoyue, Zhou Chan, et al. Rhizome dynamics and age structure of *Phragmites australis* population in heterogeneous habitats in

Zhalong Wetland[J]. *Chinese Journal of Ecology*, 2016, 35(4): 888-895.

[11] Jiao Dezhi, Jiang Qiuxu, Cao Rui, et al. Quantitative characteristics and dynamics of the rhizome of *Phragmites australis* populations in heterogeneous habitats in the Zhalong Wetland[J]. *Acta Ecologica Sinica*, 2018, 38(10): 3432-3440.

[12] Yang Yunfei, Zhang Baotian, Tian Shangyi. Dry matter storage and water soluble sugar content in different age classes rhizomes of *Phragmites communis* population in dry land habitat of Songnen Plain of China[J]. *Acta Ecologica Sinica*, 2008, 19(9): 1905-1910.

[13] Qi Zhiwei, Gao Yanna, Li Shasha, et al. A comparative study of morphology and growth traits between *Imperata cylindrica* and *Phragmites australis* under varying ground water table in the coastal wetland of Yangtze River Estuary[J]. *Chinese Journal of Applied & Environmental Biology*, 2016, 22(6): 986-992.

[14] Si Jianhua, Feng Qi, Zhang Yanwu, et al. Research on evapotranspiration and energy budget of *Phragmites australis* stand in oasis[J]. *Arid Zone Research*, 2010, 27(2): 160-168.

[15] Wang Tingting, Su Peixi, Zhou Zijuan, et al. Rhizospheric microenvironment and reed rhizome growth and development in different habitats[J]. *Arid Zone Research*, 2021, 38(1): 233-240.

[16] Xie Ting, Li Chaozhou, Jiao Jian, et al. Comparative study on the reed (*Phragmites australis*) ecophysiological response to water table changes in the Horqin Sand Land[J]. *Acta Ecologica Sinica*, 2013, 33(21): 6984-6991.

[17] Jiao Liang, Guan Xue, Liu Xuerui, et al. Functional traits of *Phragmites australis* leaves and response to soil environmental factors in inland river wetland[J]. *Arid Zone Research*, 2020, 37(1): 202-211.

[18] Du Xiaoyan, Jiao Runan, Jiao Jian, et al. Biomass allocation and allometric growth of reproductive ramets of different ecotypes of *Phragmites communis* population in Hexi Corridor[J]. *Journal of Northeast Forestry University*, 2020, 48(6): 36-41.

[19] An Jing, Wu Ling, Wang Haijuan, et al. Structural and dynamic characteristics of *Eremurus anisopterus* populations in areas with different levels of disturbance[J]. *Acta Ecologica Sinica*, 2017, 37(6): 2023-2032.

[20] Yang Fengxiang, Wang Shunqing, Xu Haigen, et al. Survival analysis theory and its application in the study of life table[J]. *Acta Ecologica Sinica*, 1991, 11(2): 153-158.

[21] Ripley B. Modelling spatial patterns[J]. *Journal of the Royal Statistical Society: Series B*, 1977, 39(2): 172-212.

[22] Zhang Jintun. Analysis of spatial point pattern for plant species[J]. *Chinese Journal of Plant Ecology*, 1998, 22(4): 3-5.

[23] Zhang Jintun, Meng Dongping. Spatial pattern analysis of individuals in different age classes of *Larix principis-rupprechtii* in Luya mountain reserve, Shanxi, China[J]. *Acta Ecologica Sinica*, 2004, 24(1): 35-40.

[24] Li Xiaodong, Ding Hui, Wu Jun, et al. Population dynamics and point pattern analysis of *Castanopsis eyrei* in Huangshan[J]. *Acta Botanica Boreali-Occidentalia Sinica*, 2018, 38(11): 2110-2119.

[25] Saydigul Haxim, Hamid Yimit. Spatial variability of soil pH value and its effect on the growth of *Phragmites australis* in Keriya Oasis: Taking Karki village as an Example[J]. *Journal of Xinjiang Normal University (Natural Sciences Edition)*, 2012, 31(2): 9-15.

[26] Svensson J S, Jeglum J K. Structure and dynamics of an undisturbed old growth Norway spruce forest on the rising Bothnian coastline[J]. *Forest Ecology and Management*, 2001, 151(1-3): 67-79.

[27] Su Zhihao, Li Wenjun, Cao Qiumei, et al. Age composition and quantitative dynamic status of *Malus sieversii* population[J]. *Arid Zone Research*, 2019, 36(5): 1153-1160.

[28] Zhang Ping, Lyu Zhaozhi, Zhang Xin, et al. Age structure of *Malus sieversii* population in Ili of Xinjiang and Kazakhstan[J]. *Arid Zone Research*, 2019, 36(4): 844-853.

[29] Liu Xiuxiang, Yang Yunfei. Allometry analysis of reproductive ramets of *Phragmites australis* populations from different habitats in the Songnen Plain of China[J]. *Acta Prataculturae Sinica*, 2012, 21(4): 313-318.

[30] Ribeiro R V, Lyra G B, Santiago A V, et al. Diurnal and seasonal patterns of leaf gas exchange in bahiagrass growing in a subtropical climate[J]. *Grass and Forage Science*, 2006, 61(3): 293-303.

[31] Zhang Shuang, Guo Chengjiu, Su Fangli, et al. Effect of salinity on the growth of reed[J]. *Journal of Shenyang Agricultural University*, 2008, 39(1): 65-68.

[32] Zhu Wenxia, Zhang Xinyan, Qian Feilong, et al. Method for rapid determination of soluble salt content in saline soil[J]. *Journal of Heilongjiang University of Technology (Comprehensive Edition)*, 2019, 19(4): 84-88.

[33] Luo Dongqi, Bai Jie, Xie Deti. Research on evaluation norm and method of soil fertility[J]. *Soil and Environmental Sciences*, 2002, 11(2): 202-205.

[34] Yang Yongfei, Zhu Tingcheng. *Plant Ecology*[M]. Beijing: Higher Education Press, 2011: 139-143.

[35] Zhao Yang, Qi Rui, Jiao Jian, et al. The population structure and dynamic characteristics of *Picea purpurea* at the Gahai-Zecha area[J]. *Acta Ecologica Sinica*, 2018, 38(20): 7447-7457.

[36] Agren J, Zackrisson O. Age and size structure of *Pinus sylvestris* populations on mires in central and northern Sweden[J]. *Journal of Ecology*, 1990, 78(4): 1049-1062.

[37] Dang H S, Jiang M X, Zhang Y J, et al. Dendroecological study of a subalpine fir (*Abies fargesii*) forest in the Qinling Mountains[J]. *Chinese Journal of Plant Ecology*, 2009, 201(1): 67-75.

Figures

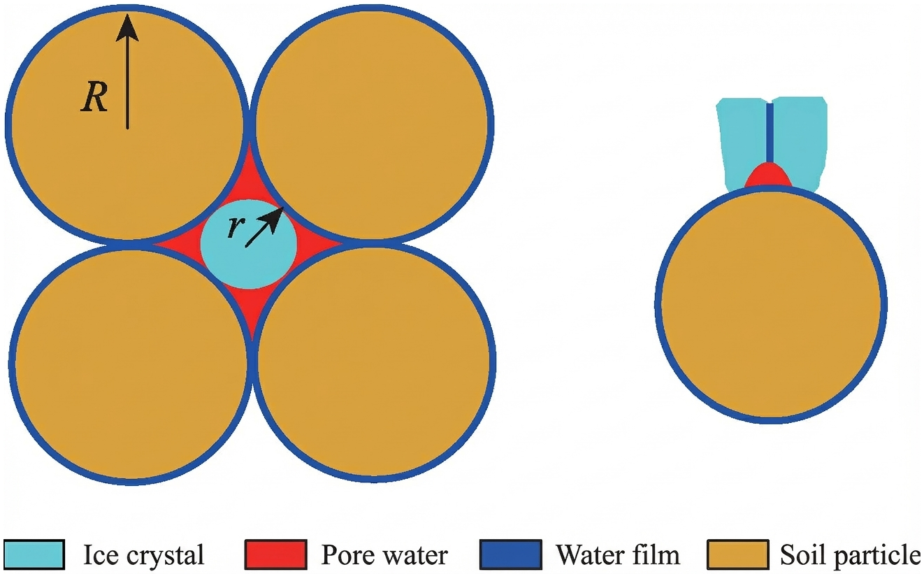

Figure 1: Figure 1

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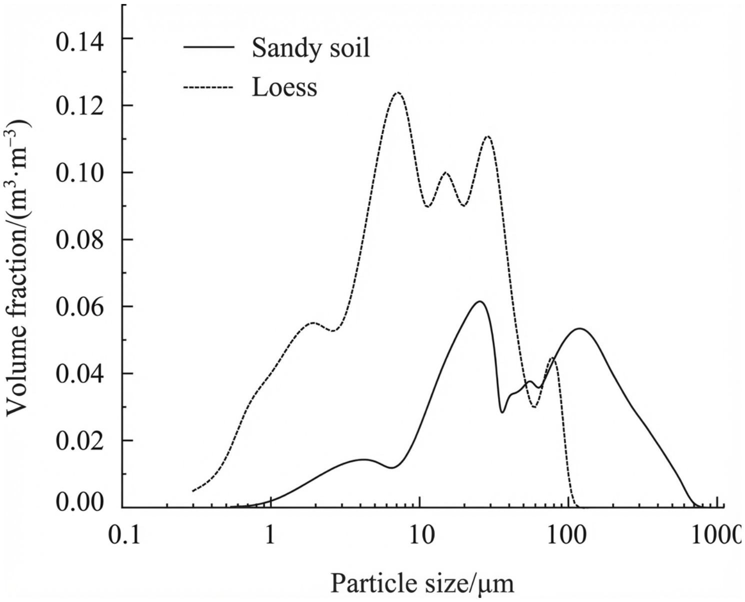

Figure 2: Figure 3

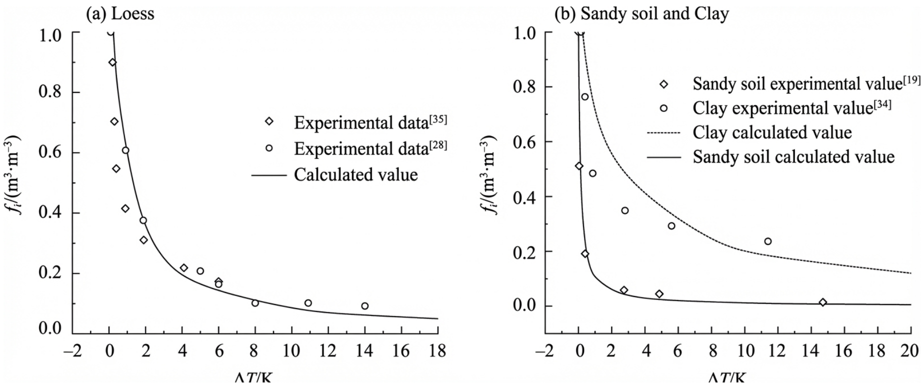

Figure 3: Figure 7