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Postprint: Photosynthetic Ecological Adaptation of Natural Desert Shrubland in West Ordos

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Abstract

To investigate the photosynthetic ecological adaptability of desert shrubs in the western Ordos region, four species of natural desert shrubs—*Helianthemum songaricum*, *Reaumuria songarica*, *Ammopiptanthus mongolicus*, and *Sarcozygium xanthoxylon*—were selected as research materials, and in-situ field measurements of diurnal and seasonal photosynthetic dynamics were conducted using a Li-6400 portable photosynthesis system. The results showed that: The optimal temperature for shrub photosynthesis differed among seasons, with high-temperature environments elevating the optimal temperature for net photosynthetic rate, while low-temperature environments lowered it. Across seasons, the diurnal variation curves of net photosynthetic rate, transpiration rate, water use efficiency, and stomatal conductance of the four shrub species exhibited a “bimodal pattern,” whereas the diurnal variation curve of intercellular CO₂ concentration displayed a “W-shaped pattern,” although the average diurnal trends of these indicators varied seasonally. The net photosynthetic capacity of the shrubs across seasons ranked as: *Ammopiptanthus mongolicus* > *Sarcozygium xanthoxylon* > *Reaumuria songarica* > *Helianthemum songaricum*, indicating that *Ammopiptanthus mongolicus* possesses strong ecological adaptability. The diurnal variation trends of net photosynthetic rate and transpiration rate remained nearly synchronized, suggesting that leaf stomata of the four shrub species were highly sensitive to environmental changes. Water is a key limiting factor for the growth and development of desert shrubs. To ensure community stability and biodiversity of desert vegetation, water management is required for *Ammopiptanthus mongolicus*, *Helianthemum songaricum*, *Reaumuria songarica*, and *Sarcozygium xanthoxylon* during summer and autumn.

Full Text

Abstract

To explore the ecological adaptability of desert shrubs in Western Ordos, four shrub species growing in this region were selected as test materials: *Helianthemum songaricum*, *Reaumuria songarica*, *Ammopiptanthus mongolicus*, and *Sarcogygium xanthoxylon*. Their photosynthetic physiological indices were measured using the Li-6400 photosynthesis system during diurnal and seasonal variations. Optimum temperature for photosynthesis varied across seasons; optimum temperature for net photosynthetic rate in desert shrubs increased in summer and decreased in winter. Diurnal variation curves for net photosynthetic rate, transpiration rate, water use efficiency, stomatal conductance, and intercellular CO₂ concentration of the four dominant desert shrubs in the three seasons were “bimodal” and assumed the shape of “W”; however, average diurnal variation trends of each index varied across seasons. Net photosynthetic rate of the four shrubs varied across seasons and followed the order of *A. mongolicus* > *C. xanthoxylon* > *R. songarica* > *H. songaricum*; thus, *A. mongolicus* showed the greatest ecological adaptability. Diurnal trends of net photosynthetic and transpiration rates were almost synchronous, indicating that stomata of these four dominant shrubs were sensitive to environmental changes. Water is a key factor limiting the growth and development of the four desert shrubs studied. To ensure the stability and diversity of desert plant communities, water management was conducted in summer and autumn for the four tested shrubs.

Keywords: ecological adaptability; photosynthesis; dominant shrubs; dynamic changes; western Ordos; Inner Mongolia

1. Study Area and Methods

1.1 Study Area Description

The study was conducted in the Western Ordos Plateau (106°44' ~107°43' E, 39°13' ~40°10' N), characterized by a temperate continental monsoon climate with arid to semi-arid conditions. The region features sparse vegetation, frequent windy conditions, and sandy soil. Meteorological data indicate average annual temperatures of 7.8–8.1 °C, with maximum temperatures reaching 33.32 °C. Measurements were taken at 13:00 during summer months when temperatures averaged 35.11 °C, and at 07:00 and 20:00 when temperatures were lower. Annual precipitation ranges from 162–172 mm, concentrated primarily in June–August, with evaporation rates of 2,470–3,481 mm. The frost-free period extends approximately 200 days, with 3,120.7 annual sunshine hours and 3,138.5 MJ·m⁻² of total solar radiation. Elevation varies between 1,500–2,100 m. Wind speeds average 3.2 m·s⁻¹, with maximum gusts reaching 24.2 m·s⁻¹.

1.2 Experimental Materials and Methods

Four dominant desert shrub species were selected: *Ammopiptanthus mongolicus* (jk), *Sarcozygium xanthoxylon* (lm), *Helianthemum songaricum* (efg), and *Reaumuria songarica* (hi). Photosynthetic measurements were conducted using a Li-6400 portable photosynthesis system during three periods: August 2015 (summer), October 2015 (autumn), and May 2016 (spring). Diurnal measurements were performed hourly from 07:00 to 20:00. Measured parameters included net photosynthetic rate (Pn), transpiration rate (Tr), water use efficiency (WUE), stomatal conductance (Gs), and intercellular CO₂ concentration (Ci). Concurrent environmental measurements recorded air temperature (Ta), relative humidity (RH), and photosynthetically active radiation (PAR). Each measurement was replicated three times per species per hour, with five replicate plants per species.

2. Results

2.1 Diurnal Variation of Net Photosynthetic Rate

The diurnal variation of Pn exhibited bimodal “W-shaped” curves across all seasons [Figure 2: see original paper]. In summer (August), Pn peaked between 10:00–15:00, with *R. songarica* showing the highest values, followed by *H. songaricum* and *A. mongolicus*. In spring (May), peaks occurred around 13:00, with *A. mongolicus* demonstrating the highest photosynthetic capacity. Autumn patterns showed intermediate values. The seasonal average Pn ranking was: *A. mongolicus* ($2.29 \text{ mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$) > *S. xanthoxylon* ($1.12 \text{ mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$) > *R. songarica* ($0.75 \text{ mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$) > *H. songaricum* ($0.69 \text{ mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$). All species showed midday depression of photosynthesis, with varying degrees of reduction.

2.2 Diurnal Variation of Transpiration Rate

Transpiration rates displayed similar bimodal patterns [Figure 3: see original paper]. Daily Tr peaks generally occurred between 12:00–15:00, coinciding with maximum temperature and PAR. *H. songaricum* maintained the highest transpiration rates ($1.26 \text{ mmol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$), followed by *S. xanthoxylon* ($0.86 \text{ mmol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$), *A. mongolicus* ($0.81 \text{ mmol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$), and *R. songarica* ($0.54 \text{ mmol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$). The diurnal trends of Pn and Tr were largely synchronous, indicating stomatal regulation of gas exchange. Seasonal variation showed summer > spring > autumn for most species.

2.3 Diurnal Variation of Stomatal Conductance

Stomatal conductance showed pronounced diurnal variation with morning and afternoon peaks [Figure 5: see original paper]. Maximum Gs values were observed between 09:00–12:00 and again at 15:00–16:00. *A. mongolicus* exhibited the highest conductance ($0.039 \text{ mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$), followed by *H. songaricum* (0.038

$\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$), *S. xanthoxylon* ($0.037 \text{ mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$), and *R. songarica* ($0.024 \text{ mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$). The data demonstrate that stomata of these desert shrubs are highly sensitive to environmental fluctuations, particularly temperature and humidity changes.

2.4 Diurnal Variation of Water Use Efficiency

Water use efficiency, calculated as P_n/Tr , showed distinct diurnal patterns [Figure 4: see original paper]. WUE peaked during morning hours (07:00–09:00) when photosynthetic rates were relatively high but transpiration was moderate. *A. mongolicus* demonstrated superior WUE across all seasons, indicating its exceptional adaptation to water-limited environments. Seasonal WUE ranking was: spring > autumn > summer, reflecting the strong water limitation during hot summer months.

2.5 Diurnal Variation of Intercellular CO₂ Concentration

Intercellular CO₂ concentration exhibited inverse relationships with P_n and G_s , showing “V-shaped” diurnal curves with minimum values during peak photosynthetic hours. C_i values ranged from 200–300 $\text{mol} \cdot \text{mol}^{-1}$ during active photosynthesis, increasing to 350–400 $\text{mol} \cdot \text{mol}^{-1}$ during midday depression periods. This pattern confirms that stomatal limitation significantly affects photosynthesis in these desert shrubs under high temperature and water stress conditions.

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