DIURNAL DYNAMICS OF PHOTOSYNTHESIS AND ENVIRONMENTAL ADAPTABILITY OF *SALIX GORDEJEVII* IN THE OTINDAG SANDY LAND, CHINA

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Abstract. Through the observation of *Salix gordejevii* in different habitats (mobile dune, semi-fixed dune, fixed dune, and dune slack) in the Otindag Sandy Land of Inner Mongolia, China, it was found that the environmental factors affecting the growth of *Salix gordejevii* varied across different habitats. By conducting photosynthetic measurements and monitoring environmental factors, the daily dynamics of these factors and photosynthetic characteristics were determined, aiming to reveal the photosynthetic physiological and ecological adaptation strategies of *Salix gordejevii*. Results show that: (a) Significant daily dynamic variations in environmental factors exist among different habitats of *Salix gordejevii*, displaying environmental heterogeneity; (b) *Salix gordejevii* exhibits significant daily variations in photosynthetic characteristics among different habitats; (c) The influence of environmental factors on plant photosynthesis (P_n) is the result of comprehensive effects. The main environmental factors affecting the P_n of *Salix gordejevii* leaves include photosynthetically active radiation (*PAR*), stomatal conductance (G_s), intercellular CO_2 concentration (C_i), leaf temperature (t_l), transpiration rate (T_r), atmospheric temperature (t_a), vapor pressure deficit (*Vpd*), and stomatal limitation (L_s). The research results contribute to a deeper understanding the decline mechanism of *Salix gordejevii* and lay a theoretical foundation for revealing its photosynthetic physiological and ecological adaptability of *Salix gordejevii*.
Keywords: *Salix gordejevii, ecological adaptation strategies, photosynthetic characteristics, environmental heterogeneity, Otindag sandy land*

Introduction

Desertification, as a serious ecological issue in today's world, poses a significant threat to human survival and development. Land desertification further exacerbates climate change, which, in turn, can accelerate soil and water loss on already degraded lands and increase the risk of forest fires due to extreme weather conditions such as drought and high temperatures, ultimately leading to more desertification. China is one of the countries most severely threatened by desertification. The primary type of desertification in China is sandy desertification, which is concentrated in the northern regions. The Inner Mongolia Autonomous Region has the largest area of desertification, covering approximately 1.1 million square kilometers. Located in central Inner Mongolia, the Hunshandake Sandy Land is one of China's four major sandy areas and is

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a typical desertification-prone region in the country, suffering from severe wind and water erosion. Excessive land reclamation and cultivation have led to grassland degradation and increased desertification, while overgrazing has further exacerbated these issues. Numerous domestic and international institutions and universities have been conducting research on ecological restoration and desertification control in the Otindag Sandy Land, exploring effective technologies and management practices to combat desertification.

Plant photosynthetic physiological ecological adaptability refers to the interrelationship between plant photosynthetic characteristics, material metabolism, energy circulation, and environmental factors (Sivagamy et al., 2024). Photosynthesis is a crucial process in natural energy conversion, playing a significant role in maintaining the balance of atmospheric oxygen and carbon dioxide, and is a fundamental physiological function of green plants (Kupika et al., 2019). Plants are susceptible to environmental factors during the physiological process of photosynthesis. The photosynthetic process in plants is mainly affected by internal physiological factors and the environment (Haque et al., 2017). Internal physiological factors affecting photosynthesis include leaf maturity, basic leaf structure, and chlorophyll content, while environmental factors such as light intensity, CO_2 concentration, temperature, and mineral nutrients also impact photosynthesis (Hao and Chu, 2021). In studies on the photosynthetic physiological ecological adaptability of plants, indicators such as chlorophyll content, net photosynthetic rate, stomatal conductance, transpiration rate, intercellular CO_2 concentration, CO_2 compensation point, and saturation point are used to represent plant photosynthetic characteristics (Feng and Zhou, 2018; Ma et al., 2017). Therefore, investigating the daily variations of plant photosynthesis and analyzing its primary influencing factors are essential approaches in studying ecological adaptability of plant photosynthetic physiology.

Salix gordejevii, as a dominant sand-fixing pioneer tree species, possesses characteristics of drought tolerance, barren soil endurance, and wind erosion resistance (Zhang et al., 2020; Tantray et al., 2020). It can form pure communities on the upper parts of sand dunes after being buried, thus playing a role in improving the ecological environment of sandy areas. In the Otindag sandy land, *Salix gordejevii*, as a dominant native tree species, is widely used in desertification control and vegetation restoration projects (Su et al., 2021). The photosynthetic rate, transpiration rate, and stomatal conductance of *Salix gordejevii* exhibit obvious threshold responses to changes in soil moisture content, indicating its adaptability to the environment (Wei and Li, 2021). *Salix gordejevii* develops certain adaptive strategies in response to heterogeneous environments in different habitats, yet the related physiological mechanisms of its ecological adaptation remain insufficiently elucidated (Feng et al., 2021; Ma et al., 2020). Therefore, this study aims to investigate the photosynthetic characteristics of *Salix gordejevii*, explore the relationship between its photosynthesis and environmental factors, and reveal the ecological adaptability of its photosynthetic physiology, using male and female seedlings of *Salix gordejevii* distributed in four different habitats within the Otindag sandy land as research subjects. The objectives of this study are: (a) to determine the different photosynthetic characteristics of *Salix gordejevii* in different habitats; (b) to analyze the correlation between the net photosynthetic rate of *Salix gordejevii* and photosynthetic factors; and (c) to provide theoretical basis for the cultivation, management, and development of *Salix gordejevii* in different habitats.

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Materials and methods

Study area

This research was conducted along the line connecting Shangdu Town, Sanggendalai Town, and Naritu Sumu (N42° 41′ – 42° 54′, E115° 41′ – 115° 59′) in Zhenglan Banner, located in the Otindag Sandy Land of Inner Mongolia Autonomous Region, China. The study area lies at an elevation of 1275 – 1341 m above sea level and features diverse sandy land types. From south to north, the sandy land types change significantly, with fixed dune, semi-fixed dune, and mobile dune being the dominant types, interspersed with intermittently distributed dune slack.

Plot arrangement

Based on comprehensive field surveys, combined with the composition and structure of plant communities and the results of interviews with local government and residents, three (50 m × 50 m) plots were selected for each of the four natural habitat types of *Salix gordejevii*. Among them, the vegetation coverage of the mobile dune plots was less than 10%, that of the semi-fixed dune plots was 15% to 40%, that of the fixed dune plots was 40% to 45%, and that of the dune slack plots was above 60%. All plots were far from residential areas, and *Salix gordejevii* was an important species in the composition of its community in all plots (*Fig. 1*).

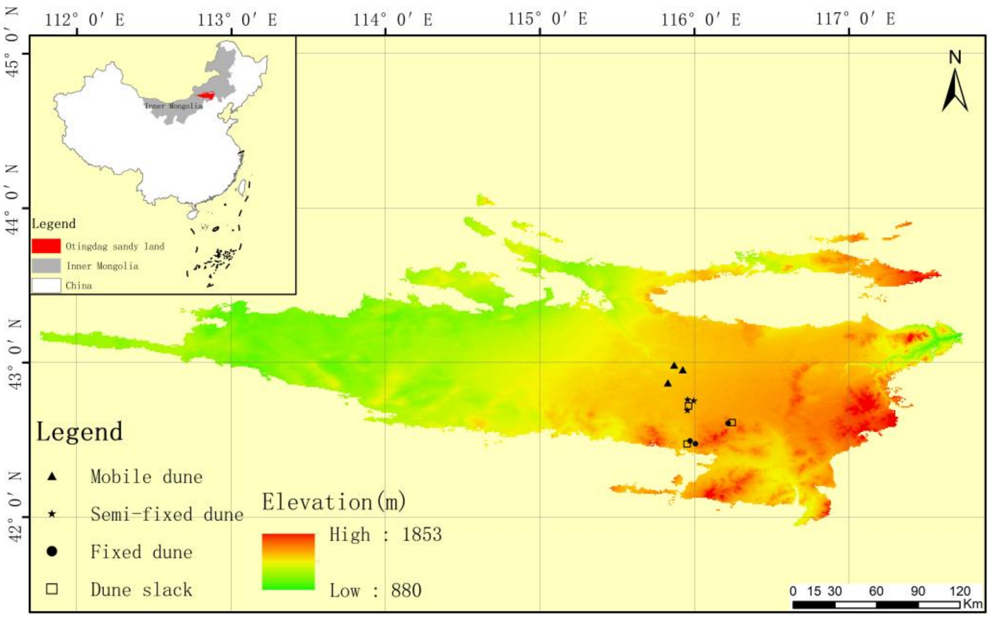

Figure 1. *Distribution diagram of Salix gordejevii populations in different habitats*

Test methods

The experiments were conducted in mid-August on clear days using the LI-6400 portable photosynthesis system (LI-COR, USA) for photosynthesis measurements and environmental factor monitoring. First, the instrument was checked and calibrated by following the on-screen instructions to adjust the CO_2 and H_2O sensors and light intensity. Then, the light source intensity (PAR), leaf chamber temperature, and CO2

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concentration (approximately 400 ppm) were adjusted, and the appropriate measurement mode was selected (“Photosynthesis” for photosynthesis rate measurement or “Gas Exchange” for gas exchange measurement). Three to five 4-year-old *Salix gordejevii* shrubs were selected in each plot, and measurements were taken on the upper part of the third or fourth fully expanded leaves of the current year’s sun-facing branches. Measurements were taken every 2 h from 7:00 to 19:00, with a total of 7 measurements per plant. The main indicators tested were net photosynthetic rate (P_n, $\mu mol \cdot m^{-2} \cdot s^{-1}$), stomatal conductance (G_s, $mmol \cdot m^{-2} \cdot s^{-1}$), stomatal limitation value (L_s, %), intercellular CO_2 concentration (C_i, μmol·mol-1), photosynthetically active radiation (*PAR*, $\mu mol \cdot m^{-2} \cdot s^{-1}$), atmospheric temperature (t_a, °C), and relative atmospheric temperature (*RH*). Soil profiles were set at typical locations in each plot, with three replicates for each habitat type.

A portable GPS locator and compass were used to record the aspect, altitude, and slope of each plot, as well as the site conditions, and the density of *Salix gordejevii* in each plot was surveyed. Each *Salix gordejevii* was measured for height and canopy width (average of north-south and east-west canopy widths). The basic characteristics of *Salix gordejevii* in different habitats were determined, and the survey results are shown in *Table 1*. The soil profile was divided into three layers: 0~20 cm, 20~40 cm, and 40~60 cm, and soil samples were collected and measured. Soil water content, bulk density, and porosity samples were taken using a soil auger, and the samples were brought back to the laboratory and dried to a constant weight. Samples from each layer were mixed after sampling at five points, with each soil sample weighing no less than 1 kg, and used to determine soil nutrients.

Table 1. *The conditions of all sites*

Site type	Sample plot number	Altitude (m)	Slope orientation	Slope (°)	Plant height (cm)	Crown width (m)	Average density ($plant \cdot hm^2$)
MD	1 2 3	1292 1275 1289	Leeward slope Leeward slope Leeward slope	15 30 22	171.93	2.33	221
SD	4 5 6	1267 1289 1341	Leeward slope Leeward slope Leeward slope	12 25 20	171.93	2.47	409
FD	7 8 9	1302 1314 1304	Gentle Gentle Gentle	− − −	252.93	2.13	125
DS	10 11 12	1323 1330 1326	Gentle Gentle Gentle	− − −	262.4	2.35	188

MD: Mobile dune; SD: Semi-fixed dune; FD: Fixed dune; DS: Dune slack

Data processing and analysis

This experiment employed a completely randomized design, and data analysis was conducted using one-way analysis of variance (ANOVA) in IBM SPSS Statistics 20. The least significant difference (LSD) method was used for multiple comparisons to

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determine differences between groups. Pearson correlation coefficients were used for correlation analysis to explore linear relationships between variables. Preliminary data processing and table preparation were carried out using Excel 2007, while final data visualization and plotting were done with Origin 21.0 software. The selection of these statistical tools and methods was based on their accuracy and practicality in handling experimental design, analyzing group differences, revealing variable correlations, and presenting data.

Results

Daily variation of environmental factors

Photosynthetically active radiation (*PAR*) showed an increasing and then decreasing trend between 7:00 and 19:00 (*Fig. 2A*), while different habitats showed significant differences. The time of peaks in different habitats was from front to back: fixed dune, dune slack, semi-fixed dune and mobile dune, which differed significantly from the other three habitats, with the lowest starting value, and an upward trend only at about 11:00 noon, and a peak (1392.8 $\mu mol \cdot m^{-2} \cdot s^{-1}$) of *PAR* at about 14:00, with a shorter period of time. Overall, it seems that the peak (1504.9 $\mu mol \cdot m^{-2} \cdot s^{-1}$) in the lowland between the mounds has the best effect of its *PAR*.

The daily variation of atmospheric temperature (t_a) was characterized by a “single-peak” curve for mobile and fixed sand, and a “double-peak” curve for semi-fixed dune and dune slack (*Fig. 2B*). The peak appeared earliest in the fixed dune, and was higher in the mobile dune than in the other habitats, with an average of 38.9°C. The initial temperature was similar in the four habitats (26°C), and was maintained at 32.5°C in the mobile dune at 19:00, while the other temperatures were all below 30°C.

The daily trend of relative humidity (*RH*) was linear, with different fluctuations in different habitats, except for the mobile dune, which was linear (*Fig. 2C*), and the other three habitats, which were in the shape of a W. The daily trend of *RH* was linear, with an increase of about 5% between 7:00 and 13:00, and an increase between 13:00 and 17:00. It decreased between 7:00 and 13:00 and increased between 13:00 and 17:00, with an increase of about 5%. The two peaks of atmospheric temperature corresponded to two valleys, respectively. During the monitoring process, the *RH* was the smallest in the semi-fixed dune, and the overall rate of decrease in the mobile dune was slower than that in the semi-fixed dune. The four habitat types had the highest *RH* values around 7:00 (48.7-58.7%), which decreased by 21.9-31.4% by 19:00.

The external vapor pressure deficit (*Vpd*) exhibits an overall trend of initial increase followed by decrease between 7:00 and 19:00 (*Fig. 2D*), with semi-fixed dune reaching the highest peak (5.6 kp) around 13:00 and a second peak around 18:00, showing larger overall vapor pressure deficits compared to other habitat types. The initial value in fixed dune (2.8 kp) is relatively high, reaching its peak (5.0 kp) earlier (around 11:00) compared to other habitats. Dune slack and mobile dune subsequently reach peaks, with peak values being similar.

Leaf temperature (t_l) exhibits an overall trend of initial increase followed by decrease, mirroring the ambient temperature variations (*Fig. 2E*). Between 7:00 and 11:00, fixed dune show higher temperatures compared to other habitats, ranging from 32.3 to 38.2°C. Between 13:00 and 18:00, semi-fixed dune exhibit relatively higher temperatures (35.0 to 38.7°C).

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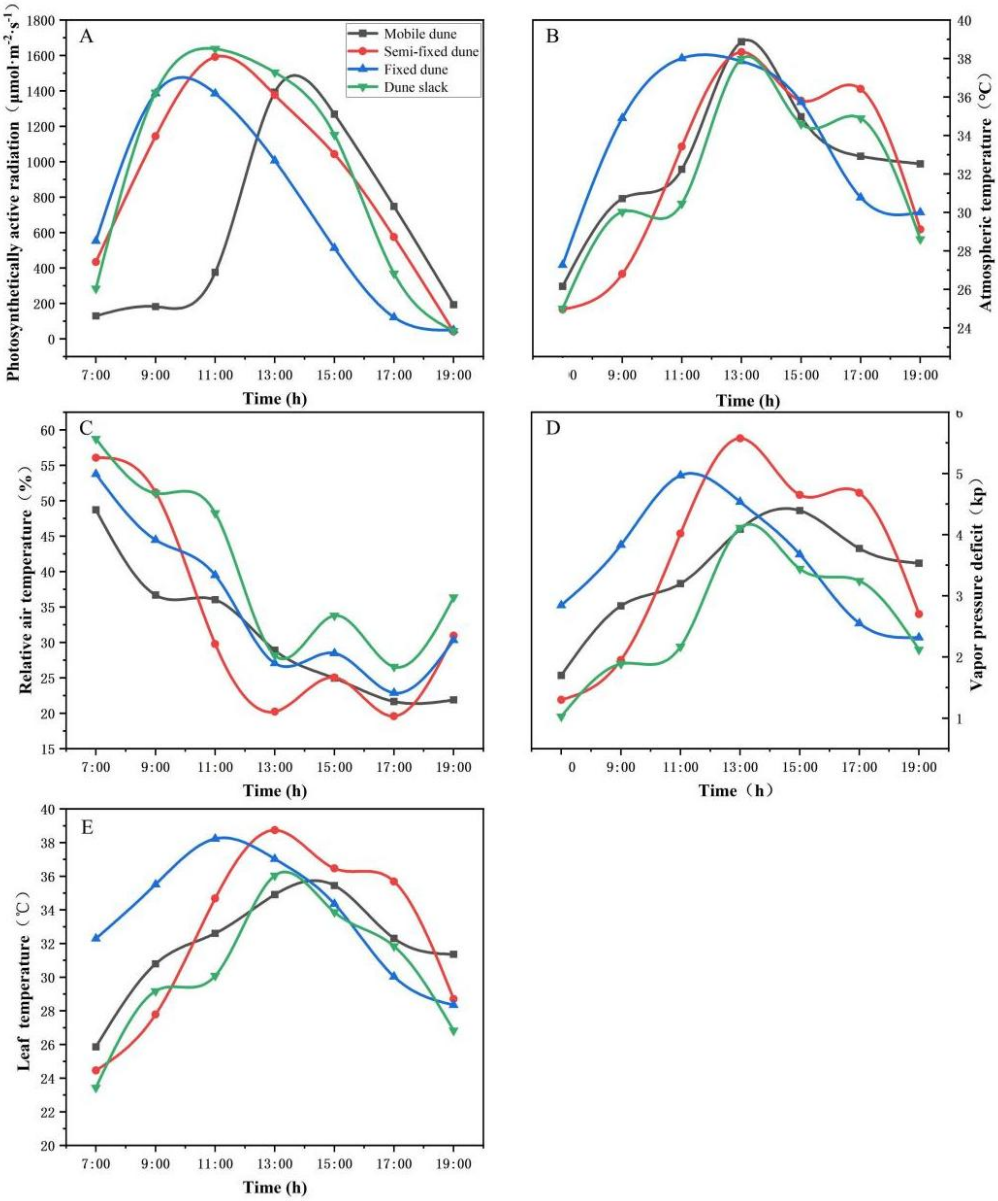

Figure 2. *Daily variation of environmental factors in different environments*

Diurnal variation of photosynthetic characteristics

Net photosynthesis rate (P_n) in mobile dune was a “single peak” curve (*Fig. 3A*), increasing from 7:00 to 11:00 and decreasing from 11:00 to 19:00, while semi-fixed dune, fixed dune and dune slack showed a non-significant “double peak” curve. In semi-fixed dune and fixed dune, P_n increases from 7:00 to 09:00 and decreases from 9:00 to 19:00, with relative stability between 13:00 and 15:00. In dune slack, P_n increases from 7:00 to 11:00, stabilizes between 13:00 and 15:00, and decreases from 15:00 to 19:00, indicating the presence of a “noon break” phenomenon for *Salix gordejevii* in dune slack habitats.

Stomatal conductance (G_s) exhibits a similar diurnal variation trend to P_n (*Fig. 3B*), with dune slack and fixed dune showing a decreasing trend. Troughs and peaks occur

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around 11:00 and 15:00, respectively, with *Salix gordejevii* in dune slack exhibiting significantly higher stomatal conductance compared to the other three habitats. In mobile dune and semi-fixed dune habitats, stomatal conductance gradually decreases, reaching troughs around 9:00 and 13:00, and peaks around 11:00 and 15:00, with the maximum peak being 0.63 mmol·m^{-2}·s^{-1}. The “noon break” phenomenon is observed in *Salix gordejevii* in both dune slack and fixed dune habitats.

The diurnal variation pattern of carbon dioxide concentration (C_i) in mobile dune, semi-fixed dune, and dune slack is similar (*Fig. 3C*), generally showing a trend of initial decrease followed by increase, with dune slack exhibiting higher C_i values compared to mobile dune and semi-fixed dune. In fixed dune habitats, the CO_2 concentration is lowest at 7:00, rises to the first peak around 9:00, decreases between 9:00 and 12:00, and then rises again between 12:00 and 19:00.

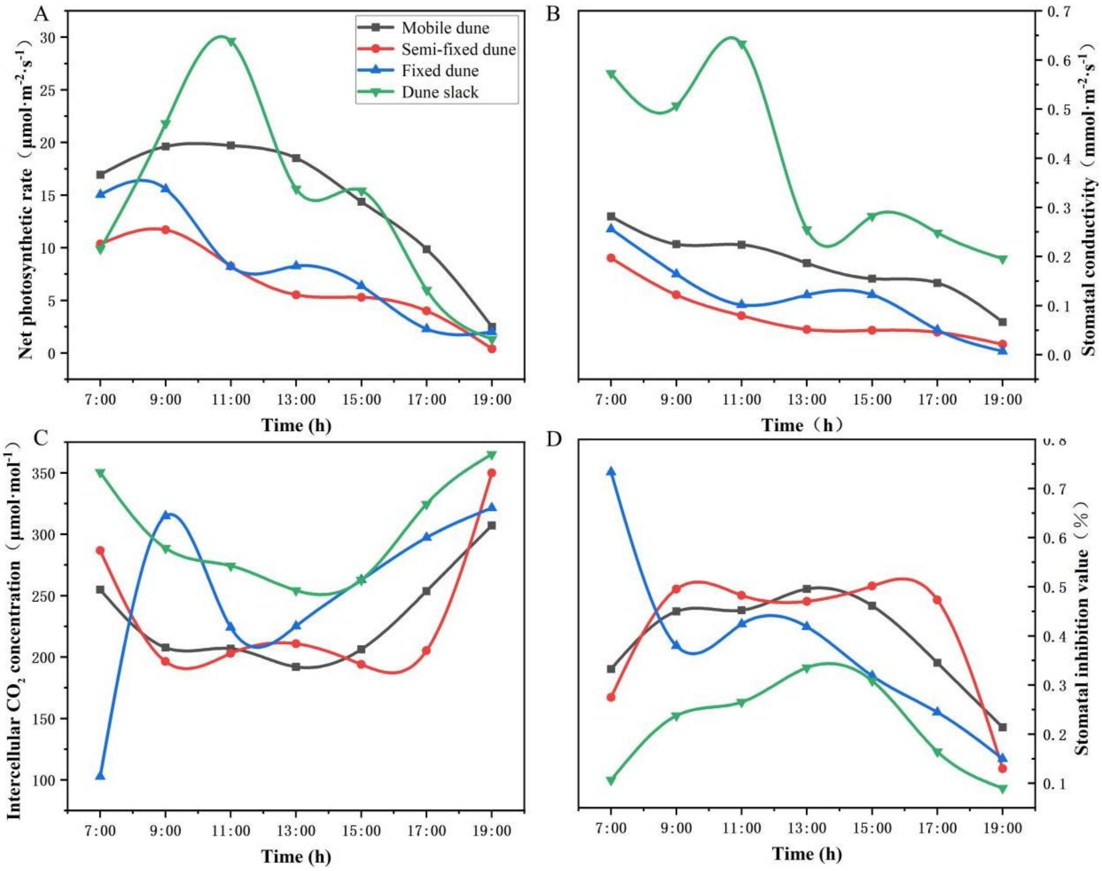

Figure 3. *Diurnal variation of Salix gordejevii photosynthetic properties in different habitats*

The diurnal variation of stomatal limitation (L_s) indicates that in fixed dune, the highest value occurs at 7:00, corresponding to the lowest intercellular CO_2 concentration in *Salix gordejevii* in this habitat. From 7:00 to 9:00, there is a continuous decline, followed by an increase from 9:00 to 13:00, and a decrease after 13:00 (*Fig. 3D*). In mobile dune and dune slack, L_s rises from 7:00 to 13:00 and falls from 13:00 to 19:00, with L_s values at each time point in mobile dune being higher than those in dune slack. In semi-fixed dune, L_s rises from 7:00 to 9:00, remains high from 9:00 to 17:00 (average L_s of 36.0%), and then decreases thereafter.

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Correlation analysis of net photosynthetic rate

The correlation between environmental factors and photosynthetic factors

Correlation analysis of environmental and photosynthetic factors in different habitats (*Fig. 4*) reveals distinct relationships. In mobile dune (*Fig. 4A*), L_s shows a positive correlation with transpiration rate (T_r), *PAR* with t_a, *Vpd* with t_a, and G_s with *RH*, all exhibiting highly significant correlations ($p < 0.001$). C_i is significantly negatively correlated with L_s and T_r ($p < 0.001$).

In semi-fixed dune (*Fig. 4D*), t_l is highly significantly positively correlated with *Vpd* and t_a, G_s with P_n, and *Vpd* with t_a ($p < 0.001$). L_s is highly significantly negatively correlated with C_i, *Vpd* with *RH*, and t_a with *RH* ($p < 0.001$).

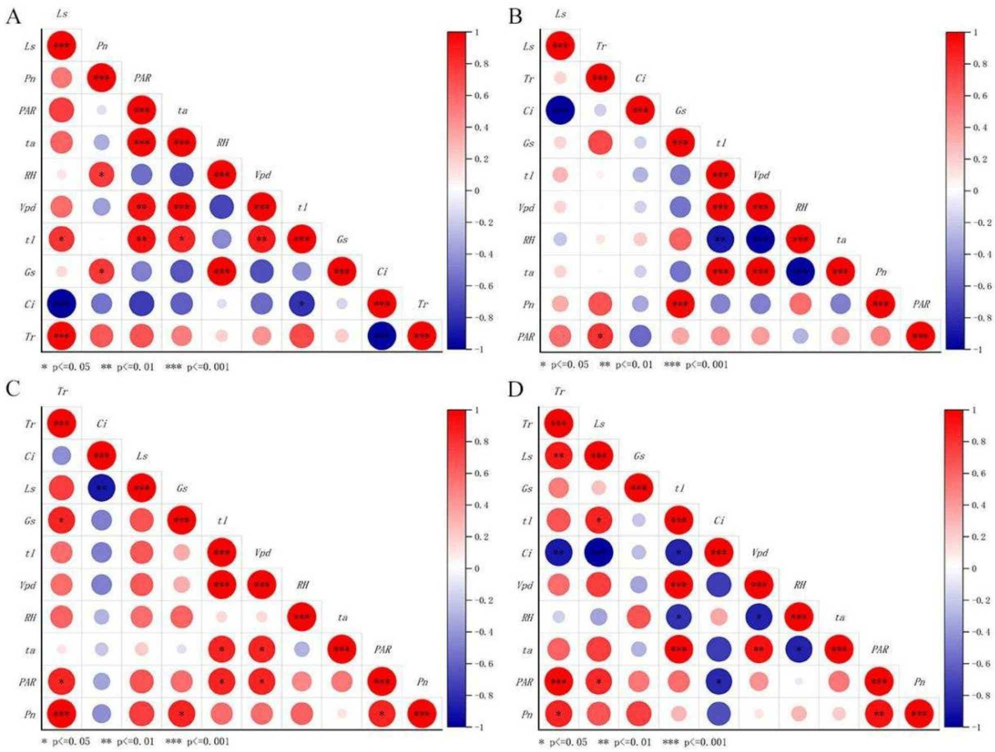

Figure 4. *Correlation between photosynthetic rate and its photosynthetic factors in different habitats. (A) Mobile dune; (B) Semi-fixed dune; (C) Fixed dune; (D) Dune slack; PAR: Photosynthetically active radiation; t_a: Atmospheric temperature; RH: Relative atmospheric temperature; Vpd: Vapor pressure deficit; t_l: leaf temperature; G_s: Stomatal conductance; C_i: Intercellular CO_2 concentration; L_s: Stomatal limitation; T_r: Transpiration rate*

In fixed dune (*Fig. 4C*), only the T_r with P_n and t_l with *Vpd* show highly significant positive correlations ($p < 0.001$).

In dune slack (*Fig. 4D*), T_r is highly significantly positively correlated with *PAR*, t_l with *Vpd*, and t_l with t_a ($p < 0.001$). L_s is highly significantly negatively correlated with C_i ($p < 0.001$).

Path analysis between net photosynthetic rate and environment

The influence of different sand habitats on P_n varies, and from the correlation analysis between net photosynthetic rate of *Salix gordejevii* in different habitat types

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and environmental and photosynthetic factors (*Fig. 5*), the top four influencing factors were identified and subjected to stepwise multiple regression analysis. For mobile dune (*Fig. 5A*), the model is: $P_n = 17.720 - 0.102\ C_i + 25.240\ G_s + 1.046\ t_l - 5.183\ Vpd$ ($R^2 = 0.998$). For semi-fixed dune (*Fig. 5B*), the model is: $P_n = 14.020 + 2.247\ T_r + 7.383\ G_s + 11.675\ L_s - 0.579\ t_a$ ($R^2 = 0.989$). For fixed dune (*Fig. 5C*) and dune slack (*Fig. 5D*), the models are: $P_n = 55.457 - 1.921\ t_l - 46.762\ G_s - 0.650\ Vpd + 6.111\ T_r$ ($R^2 = 0.934$) and $P_n = 25.521 - 1.079\ t_a + 1.699\ T_r - 5.897\ L_s + 0.009\ PAR$ ($R^2 = 0.997$), respectively.

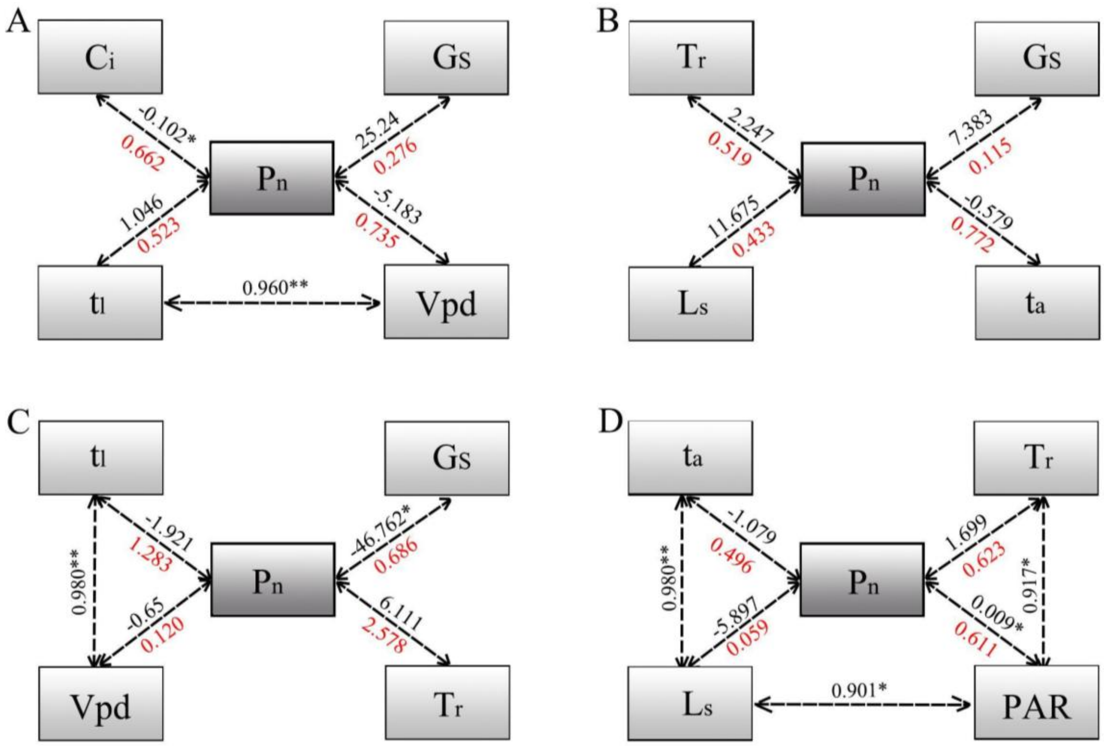

Figure 5. *Path analysis of Salix gordejevii and photosynthetic physiological ecological factors in different habitats. The black numbers represent the simple correlation coefficient with P_n; The red number represents the direct path coefficient. *Indicates significance ($p < 0.05$), ** Indicates highly significant ($p < 0.01$). (A) Mobile dune; (B) Semi-fixed dune; (C) Fixed dune; (D) Dune slack; PAR: Photosynthetically active radiation; t_a: Atmospheric temperature; Vpd: Vapor pressure deficit; t_l: leaf temperature; G_s: Stomatal conductance; C_i: Intercellular CO_2 concentration; L_s: Stomatal limitation; T_r: Transpiration rate*

Path analysis was conducted to understand the magnitude of the effect of each environmental factor. The results revealed differences in the environmental factors affecting P_n of *Salix gordejevii*. In terms of decision coefficients, for mobile sand dunes, semi-fixed dune, fixed dune, and dune slack, they are respectively $Vpd > C_i > t_l > G_s$, $t_a > T_r > L_s > G_s$, $T_r > t_l > G_s > Vpd$, and $T_r > PAR > t_a > L_s$. In mobile dune, *Vpd* is the decision variable, while G_s, L_s, and t_a are limiting factors; in semi-fixed dune, t_a is the decision variable, with T_r, G_s, and L_s as limiting factors; in fixed dune, T_r is the decision variable, with t_l, G_s, and *Vpd* as limiting factors; in dune slack, T_r is the decision variable, with t_a, L_s, and *PAR* as limiting factors.

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Discussion

The daily dynamics of environmental factors determine the growth, development, and adaptability of plants (Ba et al., 2022; Li et al., 2022). *RH* and t_a exhibit variations across different habitats, with semi-fixed dune, fixed dune, and dune slack showing a "W" shaped *RH* curve, while mobile dune display a linear pattern. The t_a in semi-fixed dune and dune slack follows a "bimodal" curve, whereas in mobile and fixed dune, it is "unimodal". The daily variations in *PAR*, *Vpd*, and t_l generally follow similar trends, though they differ temporally. Thus, significant heterogeneity exists among different habitats, influencing the photosynthetic physiology of *Salix gordejevii* in these environments. The environmental heterogeneity across habitats affects the photosynthetic physiology of *Salix gordejevii*. Photosynthetic traits are key indicators of plant adaptability, and evolution favors traits that enhance this process (Gao et al., 2009). As *Salix gordejevii* evolves, it becomes better suited to local climate and soil conditions, improving survival and aiding ecosystem restoration. Using *Salix gordejevii* as a native species, rather than introducing exotics, reduces ecological imbalance, helping preserve biodiversity and maintain environmental stability.

The diurnal dynamics of photosynthesis reflect a plant's adaptability to specific environments (Islam et al., 2022; Wu et al., 2023). In different habitats, the photosynthesis of *Salix gordejevii* shows significant daily variations. In mobile, semi-fixed, and fixed dune, there is no "noon break" phenomenon, whereas it is pronounced in dune slack. The "noon break" in photosynthesis, a response to intense light or high temperatures, is associated with *PAR* and t_a in dune slack. Photosynthetic rates are influenced by both stomatal and non-stomatal factors (Liu et al., 2020), in high temperature and light conditions, enzyme activity in mesophyll cells decreases, leading to reduced P_n. Concurrently, partial stomatal closure reduces internal CO_2 concentration, diminishing the carbon source needed for photosynthesis and lowering P_n. Analysis of the relationship between G_s and *PAR* and t_a reveals that the "noon break" in P_n of *Salix gordejevii* in dune slack is caused by stomatal closure due to strong light and high temperatures, which reduces CO_2 concentration and decreases the carboxylation capacity of mesophyll cells, leading to degradation over time. This indicates that the decline in P_n of *Salix gordejevii* is due to the combined action of stomatal and non-stomatal factors, similarly, affecting changes in P_n in mobile and fixed dune, with non-stomatal factors predominantly influencing semi-fixed dune.

Under natural conditions, the influence of environmental factors on plant P_n is not singular but rather the result of comprehensive interactions. (van de Poll and Abi Nassif, 2023). The main environmental factors affecting the leaf P_n of *Salix gordejevii* include *PAR*, G_s, C_i, t_l, T_r, t_a, *Vpd*, and L_s, all of which have both direct and indirect effects. Path analysis reveals that the primary factors influencing P_n in different habitats vary (Yang et al., 2021; Hwang, and Choo, 2017). As light intensity increases, so does t_a, which raises leaf temperature and enhances the T_r. The higher leaf temperature compared to atmospheric temperature increases the vapor pressure difference inside and outside the leaf, thereby increasing the water *Vpd*. Studies by Chun et al. (2015) and Xu et al. (2011) suggest that *PAR* and *RH*, and *PAR* and t_a, respectively, are significant factors affecting the photosynthesis of different plant species. Previous views on the relationship between P_n and environmental factors vary, mainly due to differences in species, microclimatic conditions, and the plants' adaptability to their environments (Cui et al., 2006; Jiang et al., 2023). The same genus of plants, due to different environmental conditions and local minor environmental variations in semi-arid and semi-humid areas, also shows significant

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differences in the absorption of photosynthesis. Understanding the physiological and ecological responses of *Salix gordejevii* across different habitats can enhance the success of vegetation restoration and improve ecosystem stability and resilience. Plants adapt to environmental pressures by regulating functions like photosynthesis and transpiration, which influence survival, reproduction, and community stability. Research into these adaptive mechanisms, particularly in response to changes in water, nutrients, temperature, and light, provides valuable insights for species selection, population management, and vegetation restoration strategies.

Conclusions

The photosynthetic characteristics of *Salix gordejevii* in the Otindag sandy land are closely related to environmental factors within mobile dune, semi-fixed dune, fixed dune, and dune slack, and fluctuate with changes in the overall environment. This study highlights the photosynthetic physiological and ecological adaptability of *Salix gordejevii* in arid environments, providing essential guidance for its practical application. During transplantation and management, adjusting key physiological or ecological factors based on habitat conditions can enhance photosynthesis, promoting growth and improving adaptability to various drought conditions. Regular removal of diseased, pest-infested branches, and dead leaves effectively alleviates drought stress, increasing the survival rate and resilience of *Salix gordejevii* in mobile dunes.

A deeper understanding of the photosynthetic adaptation mechanisms of *Salix gordejevii* across diverse environments offers valuable scientific insights for ecological restoration and desertification control, particularly in vegetation recovery efforts in arid regions. For example, the key seed technology for native desert xerophytic shrubs provides a strong germplasm resource guarantee for desertification control in western China’s Shagehuang region and the “Belt and Road” initiative. This technology implements the ecological desertification control model of “shrubs as the mainstay, supplemented by trees and grasses,” leading to the establishment of large-scale seed source bases for xerophytic shrubs. As a pioneer species in stabilizing sand, **Salix gordejevii* can serve as an important tool in combating desertification. Furthermore, this research advances the comprehension of plant adaptation mechanisms under extreme environmental conditions. The physiological and ecological traits of *Salix gordejevii* offer new perspectives for future ecological studies, aiding in the prediction of plant responses to climate change and shifts in their ecological functions. This knowledge not only enhances the efficiency of vegetation restoration but also provides long-term strategic insights for ecosystem management and biodiversity conservation.

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Data availability statement. The data presented in this study are available on request from the corresponding author or first author.

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