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Response of Alhagi sparsifolia Leaf Morphology and Fluorescence Parameters to Light (Postprint)

Authors: Yue Zewei, Li Chengdao, Li Lei, Li Xiangyi, Lin Lisha, Li Xiangyi

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Abstract

Taking Alhagi sparsifolia under the shelterbelt of the Cele Oasis-desert transition zone on the southern edge of the Taklamakan Desert and Alhagi sparsifolia under natural light as research objects, we studied the changes in aboveground biomass allocation, leaf morphological characteristics, chlorophyll content, and chlorophyll fluorescence kinetic parameters of Alhagi sparsifolia under different light environments. The results showed that, compared with natural light conditions: Alhagi sparsifolia under the forest canopy had higher specific leaf area but lower leaf thickness and leaf dry matter content, with significant differences in aboveground biomass allocation, showing increased leaf mass fraction and decreased assimilating branch mass fraction; Alhagi sparsifolia under the forest canopy had significantly higher chlorophyll a (Chl a) and chlorophyll b (Chl b) contents, with decreased chlorophyll a/b (Chl a/b) ratio; Alhagi sparsifolia under the forest canopy exhibited significantly higher maximum fluorescence (Fm), Photosystem II (PSII) potential activity (Fv/Fo), PSII maximum photochemical efficiency (Fv/Fm), and number of reaction centers per unit area (RC/CSo), while the energy absorbed per reaction center (ABS/RC), trapped energy (TRo/RC), and dissipated energy (DIo/RC) were lower than those in Alhagi sparsifolia under control conditions. In the shaded environment, in addition to responding to changes in light environment by altering aboveground biomass allocation and leaf morphological characteristics of Alhagi sparsifolia, changes in the chlorophyll a/b (Chl a/b) ratio, improvement in PSII photochemical efficiency, and increase in reaction center number are also important physiological pathways for Alhagi sparsifolia to adapt to shaded conditions. Better utilization of light resources and responsive characteristics at morphological and physiological levels constitute the primary mechanisms for Alhagi sparsifolia to adapt to low-light environments.

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Full Text

Responses of Leaf Morphology and Fluorescence Parameters of *Alhagi sparsifolia* in Different Light Environments

YUE Ze-wei[1,2,3], **LI Cheng-dao**[1,2,3], **LI Lei**[1,2,3], **LI Xiang-yi**[1,2,3], **LIN Li-sha**[1,2,3]

[1] State Key Laboratory of Desert and Oasis Ecology, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, Xinjiang, China
[2] Cele National Station of Observation and Research for Desert Grassland Ecosystems, Cele 848300, Xinjiang, China
[3] University of Chinese Academy of Sciences, Beijing 100049, China

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Corresponding author: LI Cheng-dao. E-mail: lixy@ms.xjb.ac.cn

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1.3 Methods

1.3.1 Chlorophyll Fluorescence Measurements Chlorophyll fluorescence parameters were measured using a PAM-2500 fluorometer (Heinz Walz GmbH, Effeltrich, Germany). Leaf clips were attached to mature, healthy leaves for 15 minutes of dark adaptation before measurement. The measuring light intensity was $0.01\ \ \mathrm{mol \cdot m^{-2} \cdot s^{-1}}$, with saturating pulses of $3000\ \ \mathrm{mol \cdot m^{-2} \cdot s^{-1}}$ applied for 20 minutes to determine fluorescence kinetics. The following parameters were calculated: maximum photochemical efficiency of PSII (Fv/Fm) = (Fm - Fo)/Fm; absorption flux per reaction center (ABS/RC) = Mo/Vj/(Fv/Fm); trapping flux per reaction center (TRo/RC) = Mo/Vj; dissipated energy flux per reaction center (DIo/RC) = ABS/RC - TRo/RC; and active reaction centers per cross-section (RC/CSm) = (Fv/Fm) × (Vj/Mo) × Fo, where Fv is variable fluorescence, Fm is maximum fluorescence, Fo is minimum fluorescence, and Vj is relative variable fluorescence at the J-step.

1.3.4 Leaf Dry Matter Content (LDMC) Leaf dry matter content was calculated as: LDMC (mg/g) = leaf dry mass (mg) / leaf fresh mass (g). Samples were oven-dried at 65°C to constant weight before measurement.

1.3.6 Chlorophyll Content Determination Chlorophyll was extracted from 25 mg fresh leaf material in 25 mL of 95% ethanol at 4°C for 24 hours in darkness. Absorbance was measured at 752 nm using a spectrophotometer, and chlorophyll concentrations were calculated according to standard formulas [18].

1.4 Statistical Analysis

Data were processed using Microsoft Excel 2010 and analyzed with SPSS 20.0. One-way ANOVA was performed to test for significant differences between treatments, followed by LSD post-hoc tests for multiple comparisons. Figures were generated using Origin 9.0. All data are presented as means ± standard error, with significance levels set at $P < 0.05$ and $P < 0.01$.

2 Results

2.1 Leaf Morphological Characteristics **Table 1** shows the changes in leaf thickness, specific leaf area (SLA), and leaf dry matter content of *A. sparsifolia* under different light conditions. Understory plants exhibited significantly lower leaf thickness (13.33% reduction), higher SLA (14.41% increase), and lower leaf dry matter content (14.96% reduction) compared to sun-grown plants ($P < 0.01$). These morphological adjustments represent typical shade-acclimation responses.

Table 1 Changes in leaf thickness, specific leaf area, and leaf dry matter content of *Alhagi sparsifolia* in different light environments

Treatment	Leaf thickness ($cm^2 \cdot g^{-1}$)	SLA ($cm^2 \cdot g^{-1}$)	Leaf dry matter content ($mg \cdot g^{-1}$)
Sunlight	0.60 ± 0.02b	93.17 ± 2.15b	207.99 ± 6.64b
Understory	0.52 ± 0.01a	106.60 ± 2.33a	176.87 ± 6.08a
Change (%)	-13.33	14.41	-14.96

Note: Different letters indicate significant differences at $P < 0.01$ level.

2.2 Chlorophyll Content **Table 2** presents the chlorophyll content variations. Understory plants showed substantially higher chlorophyll a (52.00% increase) and chlorophyll b (100.00% increase) contents, leading to a 24.32% decrease in the Chl a/b ratio ($P < 0.01$). Total chlorophyll content increased by 64.36% in understory plants compared to sun-grown plants.

Table 2 Changes in chlorophyll content of *Alhagi sparsifolia* in different light environments

Treatment	Chl a ($mg \cdot g^{-1}$)	Chl b ($mg \cdot g^{-1}$)	Total Chl ($mg \cdot g^{-1}$)	Chl a/b ratio
Sunlight	0.75 ± 0.08b	0.26 ± 0.09b	1.01 ± 0.12b	2.92 ± 0.15a
Understory	1.14 ± 0.01a	0.52 ± 0.03a	1.66 ± 0.04a	2.21 ± 0.09b

Treatment	Chl a (mg · g^{-1})	Chl b (mg · g^{-1})	Total Chl (mg · g^{-1})	Chl a/b ratio
Change (%)	52.00	100.00	64.36	-24.32

2.3 PSII Fluorescence Parameters Diurnal variations in minimal fluorescence (Fo) showed distinct patterns between treatments. Understory plants exhibited significantly lower Fo values at 14:00 compared to sun-grown plants ($P < 0.01$). The maximum fluorescence (Fm), potential PSII activity (Fv/Fo), and maximum photochemical efficiency (Fv/Fm) were consistently higher in understory plants throughout the day, with peak values observed at 16:00. These results indicate enhanced photochemical capacity under shaded conditions.

2.4 PSII Energy Flow Parameters Energy flux parameters per reaction center demonstrated that understory plants had significantly lower absorption flux (ABS/RC), trapping flux (TRo/RC), and dissipation flux (DIo/RC) compared to sun-grown plants ($P < 0.05$). Conversely, the number of active reaction centers per cross-section (RC/CSm) was substantially higher in understory plants, suggesting improved light-harvesting efficiency under low-light conditions.

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3 Discussion

The observed morphological and physiological adjustments in *A. sparsifolia* represent comprehensive shade-acclimation strategies. The increased SLA and reduced leaf thickness in understory plants enhance light capture efficiency by maximizing surface area for photon interception [19]. Concurrently, higher chlorophyll content, particularly Chl b, optimizes absorption of diffuse light in the green spectrum, while the reduced Chl a/b ratio facilitates more efficient energy transfer to reaction centers [20].

The enhanced PSII photochemical efficiency (Fv/Fm) and increased density of active reaction centers (RC/CSm) in understory plants indicate improved conversion of captured light energy into photochemical work. Lower energy dissipation (DIo/RC) suggests reduced photoinhibitory stress under shaded conditions. These physiological modifications, combined with morphological plasticity, enable *A. sparsifolia* to maintain positive carbon balance in low-light environments typical of forest understories [21-25].

The diurnal patterns of Fo and Fm reflect dynamic photoprotective mechanisms. The midday depression in Fo in understory plants likely represents optimization of photosynthetic apparatus to transient high-light periods, while maintaining elevated Fv/Fm indicates robust photochemical capacity [11]. This plasticity is crucial for survival in variable light conditions characteristic of desert-oasis ecotones.

4 Conclusion

Alhagi sparsifolia exhibits remarkable phenotypic plasticity in response to light environment variation. The coordinated adjustment of leaf morphology (increased SLA, reduced thickness) and physiology (enhanced chlorophyll content, improved PSII efficiency) constitutes an effective strategy for optimizing light utilization in shaded habitats. These adaptive traits are essential for the species' survival and performance in forest protection systems and other low-light environments within arid regions.

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