Variation in Photosynthetic Characteristics of Moso Bamboo under Different Management Regimes (Postprint)

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Abstract

Forest management practices are closely related to light, temperature, water, and nutrient patterns within the forest, affecting plant photosynthetic performance. To investigate the photosynthetic response characteristics of Moso bamboo (Phyllostachys edulis) to different management practices, a study was conducted on five types of Moso bamboo forests under three management regimes in Huangshan District, Anhui Province, namely: extensive management (I), moderate management (II), and intensive management (III—winter shoot harvesting rate 10%-15%, IV—winter shoot harvesting rate 15%-20%, V—winter shoot harvesting rate approximately 10% with nitrogen fertilizer applied in September each year). The results showed that: 1) Significant differences existed in leaf area index (LAI) and SPAD values of Moso bamboo under different management practices, with LAI and SPAD values fluctuating and increasing with management intensity. 2) The light response curves exhibited consistent trends, with satisfactory fitting by the non-rectangular hyperbola model and determination coefficients all exceeding 0.96. As photosynthetically active radiation (PAR) increased, net photosynthetic rate (Pn), stomatal conductance (Cd), transpiration rate (Tr), and intercellular CO2 concentration (Ci) decreased accordingly. The overall variation levels under non-intensive management (I, II) were higher than those under intensive management (IV and III), but treatment V under intensive management showed trends closer to I and II, indicating that intensive management with appropriate nutrient supplementation (V) could effectively enhance the light energy utilization capacity of Moso bamboo. 3) Under the two management practices where the three parameters—light saturation point (LSP), light compensation point (LCP), and dark respiration rate (Rd)—were either all at their maximum or all at their minimum, the Moso bamboo forests exhibited higher adaptability, manifested as significantly higher maximum net

photosynthetic capacity (Pnmax) compared to bamboo forests under other management practices. It can thus be inferred that Moso bamboo under extensive management (I) or intensive management with effective forest nutrient supplementation (V) possesses higher photosynthetic capacity.

Full Text

Preamble

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Study on Photosynthetic Characteristic Differentiation of Moso Bamboo Under Different Management Modes

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Abstract

Forest management modes are closely related to the patterns of light, water, and nutrient availability within forest stands, all of which influence photosynthetic capacity. To investigate how photosynthetic characteristics of Moso bamboo (*Phyllostachys edulis*) respond to different management intensities, we studied five bamboo forest types in Huangshan District, Anhui Province: ( ) extensively managed stands with minimal human disturbance; ( ) moderately managed stands with some selective cutting; and three intensively managed stands including ( ) 10%–15% winter shoot harvesting, ( ) 15%–20% winter shoot harvesting, and ( ) less than 10% winter shoot harvesting with annual fertilization each September. The results showed that: (1) Significant differences existed in leaf area index (LAI) and soil plant analyzer development (SPAD) values among management modes, with variability increasing with management intensity. (2) Light-response curves showed similar patterns across all management modes, with the non-rectangular hyperbola model providing the best fit (coefficients of determination >0.96). With increasing photosynthetically active radiation (PAR), net photosynthetic rate (Pn) and transpiration rate (Tr) increased while intercellular CO_2 concentration (Ci) decreased. Photosynthetic characteristics were generally higher in non-intensively managed stands (modes and) compared to intensively managed stands. (3) Among all parameters, fertilized intensive management (mode) exhibited the highest maximum net photosynthetic capacity (Pmax), while extensive management showed the highest light saturation point (LSP) and light compensation point (LCP). These findings indicate that appropriate nutrient supplementation can effectively en-

hance bamboo' s light energy utilization efficiency, and that stands under extensive management or fertilized intensive management demonstrate superior photosynthetic performance and adaptability.

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Measurement Items and Methods

Photosynthetic Parameter Measurement

Photosynthetic measurements were conducted during the peak growing season of on-year Moso bamboo on clear, sunny days with abundant light. A standard leaf chamber equipped with a red-blue light source was used to determine light-response curves for sample bamboo plants across all management modes. Environmental conditions were controlled at a leaf temperature of 28°C and CO_2 concentration of 400 mol/mol. To ensure consistency across measurements, all observations were performed between 7:30 and 11:00 AM. Photosynthetically active radiation was incrementally increased from weak to strong intensities at the following levels: 0, 30, 50, 100, 200, 300, 500, 800, 1200, 1500, 1800, and 2200 mol m^{-2} s^{-1}. Leaves were allowed to acclimate for 3–5 minutes at each PAR level before measurement. To correct for potential errors when bamboo leaves did not completely fill the leaf chamber, measured leaves were numbered, marked, cut, and brought back to the laboratory for leaf area determination using grid paper, with subsequent recalculation of photosynthetic parameters. Due to the high flexibility of Moso bamboo, target culms were gently bent to enable in situ measurement of photosynthetic characteristics. Primary measured parameters included net photosynthetic rate (Pn), transpiration rate (Tr), stomatal conductance (Cd), intercellular CO_2 concentration (Ci), photosynthetically active radiation (PAR), air temperature (Ta), relative humidity (RH), and leaf temperature (Tleaf).

Leaf Area Index and Chlorophyll Content Determination

Leaf area index was measured using a Hemiview digital canopy analyzer. Within each standard plot, five fixed sampling points were established along the diagonal and at the center. Measurements were taken during overcast conditions or during early morning (6:30–8:30) and late afternoon (16:30–18:00) on clear days to avoid overexposure from direct sunlight. The canopy analyzer was maintained at a height of 1.5 m to exclude understory vegetation interference. At each fixed point, three measurements were taken to minimize overlap in field of view, with LAI subsequently calculated using the instrument' s analysis software. Chlorophyll content was assessed using a SPAD-502 chlorophyll meter on healthy leaves from the upper canopy of target bamboo plants, with three leaves measured per replicate and values averaged.

Data Processing

Preliminary data analysis was conducted using Excel 2010 to calculate average net photosynthetic rates under different light intensities for each management mode. Light-response curves and associated photosynthetic parameters were then derived using non-linear regression models. Statistical analyses were performed using SPSS 16.0 software. The non-rectangular hyperbola model was employed for fitting Pn-PAR relationships:

$$Pn = \frac{PAR \times AQE \times Pmax}{PAR \times AQE + Pmax} - Rd$$

where Pn is net photosynthetic rate (mol m^{-2} s^{-1}), PAR is photosynthetically active radiation intensity (mol m^{-2} s^{-1}), AQE is apparent quantum efficiency (mol/ mol), Pmax is maximum net photosynthetic rate (mol m^{-2} s^{-1}), and Rd is dark respiration rate (mol m^{-2} s^{-1}).

Results

Leaf Area Index of Moso Bamboo

LAI varied significantly among management modes, following the trend: (1.39) < (1.54) < (1.56) < (1.63) < (1.76). The extensively managed stands (modes and) showed no significant difference between them, but both were significantly lower than the intensively managed stands ($p < 0.05$). This indicates that while extensive and moderate management have minimal impact on LAI, intensive management practices create substantial differences. Among intensively managed stands, fertilized plots (mode) exhibited significantly higher LAI than those with only shoot harvesting (modes and). Furthermore, stands without distinct on-year/off-year patterns demonstrated higher LAI than those with clear alternation cycles, suggesting that continuous culm retention contributes to greater leaf area development.

SPAD Values of Moso Bamboo Leaves

SPAD values, which reflect relative chlorophyll content and nitrogen status, also differed significantly among management modes. Extensively managed stands maintained relatively stable SPAD values, likely due to balanced internal nutrient cycling that is not easily disrupted. In contrast, intensively managed stands with high cutting intensity showed significantly lower SPAD values, indicating that excessive harvesting substantially impacts nitrogen cycling and utilization within bamboo leaves.

Basic characteristics of study plots

[FIGURE:1] Bamboo forest LAI under different management modes

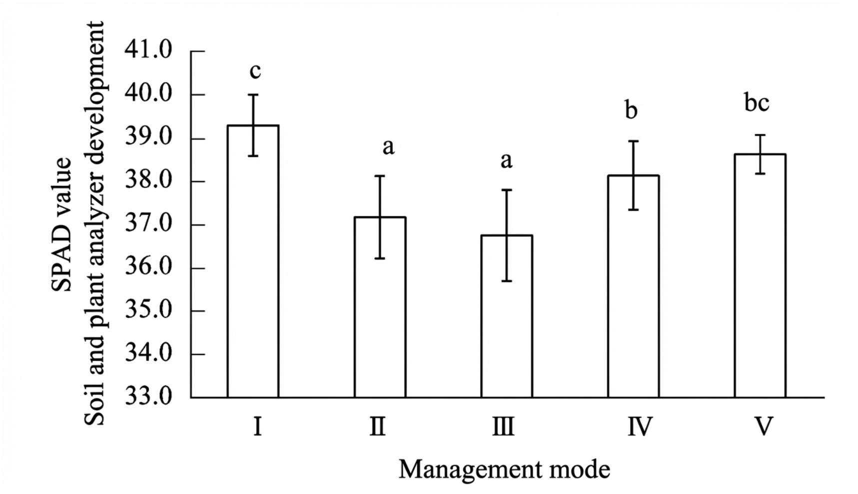

Figure 1: Figure 2

Bamboo leaf SPAD values under different management modes

Light-Response Curves

Light-response curves for all five management modes were well-fitted by the non-rectangular hyperbola model, with coefficients of determination exceeding 0.96. The curves revealed consistent trends across management modes, with net photosynthetic rate increasing rapidly with PAR before plateauing when light saturation was reached. This indicates that bamboo' s photosynthetic response to light energy varies by management intensity. Overall, Pn values ranked as: > > > > , with extensive and moderate management showing higher photosynthetic capacity than intensive management. Notably, fertilized intensive management (mode) exhibited superior photosynthetic performance compared to shoot-harvesting-only intensive management, demonstrating that appropriate nutrient supplementation can enhance light energy utilization efficiency.

Stomatal Conductance

Stomatal conductance increased with PAR across all management modes, with the fastest increase occurring below 200 mol m^{-2} s^{-1} and slowing after 1200 mol m^{-2} s^{-1}. The ranking of Cd values was: (0.022–0.174 mol/ mol) > (0.042-0.168 mol/ mol) > (0.031-0.161 mol/ mol) > (0.027-0.141 mol/ mol) > (0.022–0.133 mol/ mol). This pattern indicates that without proper nutrient supplementation, intensive management results in lower stomatal conductance compared to extensive management. Practical management should therefore consider nutrient supplementation or reduced disturbance levels to improve stomatal function.

[FIGURE:3] Bamboo light-response curves under different management modes

[FIGURE:4] Bamboo Cd under different management modes

Intercellular CO_2 Concentration

Intercellular CO_2 concentration decreased with increasing PAR across all management modes, with the most rapid decline observed in extensively managed stands. At PAR levels below 200 mol m^{-2} s^{-1}, Ci values were similar across modes, but differences became more pronounced above 200 mol m^{-2} s^{-1}, with mode showing the highest Ci at 88 mol/ mol under low light conditions, indicating superior photosynthetic efficiency in weak light.

Transpiration Rate

Transpiration rate increased gradually with PAR, rising rapidly below 200 mol m^{-2} s^{-1} before slowing at higher light levels. The overall ranking of Tr values was: > > > > , showing a pattern similar to that of stomatal conductance.

[FIGURE:5] Bamboo Ci under different management modes

[FIGURE:6] Bamboo Tr under different management modes

Variation in Light-Response Curve Parameters

Photosynthetic parameters derived from light-response curves showed substantial variation among management modes. Apparent quantum efficiency ranged from 0.029 to 0.034 across modes, indicating that while bamboo's capacity to absorb, convert, and utilize light energy under weak illumination differed slightly, management intensity had minimal effect on this parameter. Maximum net photosynthetic rate (Pmax) showed greater variation, following the order: > > > > . Light saturation point (LSP) ranked as: > > > > , while light compensation point (LCP) followed: > > > > . Dark respiration rate (Rd) was highest in extensively managed stands (> > > >), indicating strong respiratory activity even under dark conditions, whereas fertilized intensive management (mode) effectively reduced dark respiration rates below all other treatments.

Bamboo forest light-response curve simulation parameters under different management modes

Discussion and Conclusion

Moso bamboo is characterized by rapid growth and versatile utility, making profit-driven management practices common in bamboo forests. Typical management involves biennial harvesting for timber or shoot production, with relatively extensive historical practices. However, harvesting significantly affects soil respiration, nutrient balance, and stand structure. Research indicates that annual harvesting of 9.0 $t \cdot hm^{-2}$ can increase soil temperature and alter soil respiration and litter decomposition, while causing nutrient losses totaling 7.96 kg/hm^{-2} of N, P, K, Ca, Mg, and Si. Long-term differential management creates habitual effects on temperature and light environments within bamboo stands, which are intimately linked to photosynthetic requirements.

Our results demonstrate that photosynthetic characteristics vary significantly among management modes. Extensively managed stands (modes and) showed higher Pn, Tr, LSP, and LCP, along with relatively high Rd, compared to intensively managed stands. This indicates that human disturbance is a primary driver of photosynthetic differentiation. In low-disturbance extensive management, the ecosystem maintains systematic self-renewal and balance, consistent with ecological principles. Once human factors are introduced, ecosystem development tends toward diversification, as evidenced by the varied photosynthetic performance among intensively managed stands.

Integrating bamboo' s biological characteristics with site conditions, intensively managed stands with appropriate nutrient supplementation (mode) exhibited high photosynthetic capacity, consistent with previous research on fertilization effects. However, optimal fertilization timing, dosage, and frequency remain unresolved. The on-year/off-year pattern represents a typical feature of Moso bamboo forests, though its underlying mechanisms are not fully understood. Our study compared stands with and without distinct size-year patterns, finding that non-separated-year stands had significantly higher LAI and SPAD values, with consistent trends in Pn, Tr, and Ci, suggesting stronger adaptability to high light conditions. The higher LAI in non-separated-year stands may result from annual shoot production and more frequent changes in individual culm growing space, with competition intensity positively correlated with stand density and leaf area index.

Harvesting shoots substantially disturbs stand structure and soil conditions, creating environmental uncertainty. The differentiation in photosynthetic characteristics reflects long-term adaptation to varying light and nutrient conditions under different management regimes. Therefore, bamboo forest management should select appropriate measures based on actual conditions to balance economic, ecological, and social benefits.

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