

Leaf gas exchange of lettuce in response to temperature, light intensity, and acclimation time

Light energy is the driving force of photosynthesis. For indoor production facilities, sole-source lighting is used as a primary lighting source substituting sunlight. Meanwhile, supplemental lighting is widely used in greenhouse production where sunlight is limited or highly variable to meet minimum or adequate daily light integral (DLI).

Conventionally, the supplemental light levels are controlled based on ambient sunlight levels so that the lighting can be turned on when the sunlight level is below a specific threshold. However, as temperature significantly affects photosynthetic efficiency as well as light intensity, temperature conditions should also be considered for optimal light control. For example, high temperature limits photosynthetic capacity by reducing Rubisco activity, inhibiting chlorophyll biosynthesis, inactivating photosystem II (PSII), disorganizing thylakoid, and increasing energy dissipation (Baker and Rosenqvist, 2004; Mathur et al., 2014). Whereas low temperature might induce photoinhibition and low photosynthetic efficiency especially when combined with high light intensity (Zhou et al., 2019).

Additionally, photosynthetic performance changes over time due to the acclimation. High-light-adapted plants have higher photosynthetic efficiency than shade-adapted

plants, indicating that those plants can use supplemental light more efficiently (Zhen and van Iersel, 2017). Even though the photosynthetic rate decreases under extreme temperatures in the short term, plants can show the best photosynthetic performance after acclimation under their previous growing condition despite suboptimal temperature conditions (Hikosaka et al., 2006). Reporting only the short-term responses of plants under specific environmental conditions might be misleading. Hence, supplemental light control should be tailored based on light intensity, temperature, and acclimation time to optimize light use efficiency so that growers can provide light energy only when the photosynthetic efficiency is maximized.

To investigate photosynthetic activity changes in response to temperature, light intensities, and acclimation time, we measured leaf gas exchange of lettuce plants under different temperature conditions (18, 25, and 32 °C) and light intensities (150 or 500 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) with four replicates. Photosynthetic rate was measured 2 and 7 days after the treatment (DAT), and photosynthetic rate vs. intercellular CO_2 concentration (A/C_i) curves were constructed 7 days after the treatment using a CIRAS-3 Portable Photosynthesis System. The high-speed CO_2

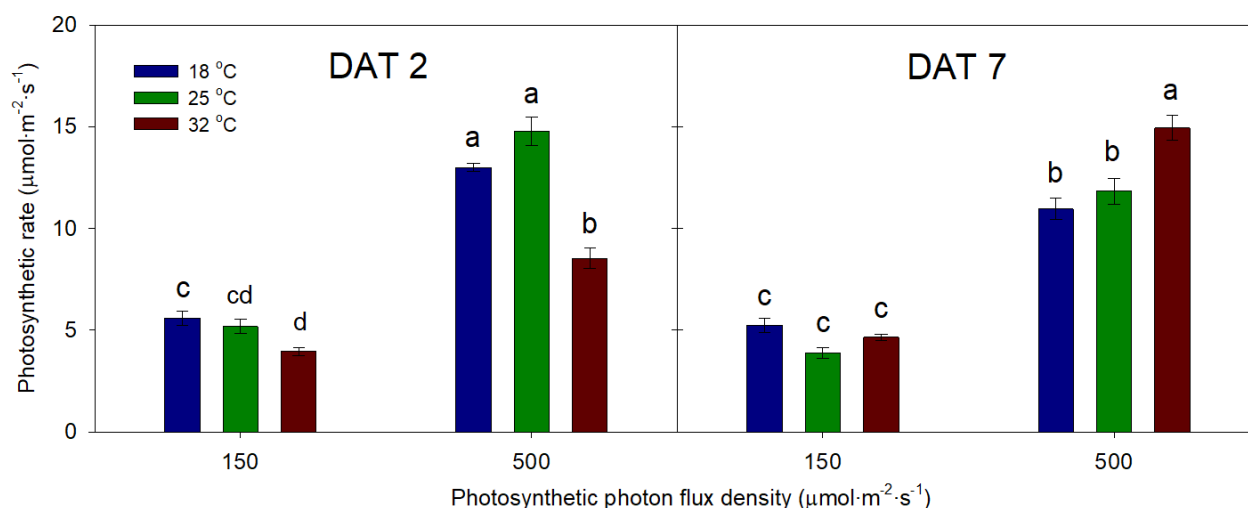


Figure 1.

Photosynthetic rate of uppermost fully expanded lettuce leaves ($n = 4$) measured at 2 days after treatment (DAT) (left) and 7 DAT (right). The photosynthetic rate was measured under different light intensities (150 or 500 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) and temperature conditions (18, 25, and 32 °C). Error bars indicate the standard errors ($n = 4$).

ramping technique (SSCO₂ R™) by PP systems was used for A/C_i curves that enable researchers to create each curve within 7 minutes, and it has been proved that there is no significant difference between the ramping technique and the traditional steady-state A/C_i technique (Ertle et al., 2023). The A/C_i curves were fitted by the method of Sharkey et al. 2007 to calculate Rubisco carboxylation, the maximum rate of electron transport, and the maximum rate of triose phosphate utilization rate.

Under low light intensity, photosynthetic rate was relatively similar among different temperatures indicating that the light intensity was the limiting factor, not the temperature condition (Fig. 1.). The photosynthetic rate of 32 °C under high light was significantly lower than other temperature conditions at DAT 2 but became even higher at DAT 7 (Fig. 1.). Lettuce plants might have experienced immediate heat stress with increased photorespiration in early stage, however, they could recover and acclimate to the high temperature over time.

A/C_i curves showed similar results from the photosynthetic rate at 7 DAT. While the maximum rate of electron transport and triose phosphate utilization rate were constant among temperature conditions in both low and high light intensities, Rubisco carboxylation of 32 °C at high light was significantly higher than in lower temperature conditions (Fig. 2.). This implies that Rubisco carboxylation was the limiting factor that was highly activated under high temperature. However, electron transport through Photosystem II and triose phosphate utilization are optimized for a broader temperature range, so they were not the limiting factor for CO₂ assimilation in this study.

By utilizing portable photosynthesis systems such as CIRAS-3 and CIRAS-4, the gas exchange responses of plants under specific environmental conditions (temperature, light intensity, light spectrum, and humidity) can be easily measured. Additionally, measuring them repetitively over time might be essential to investigate the plant's acclimation process as a long-term response.

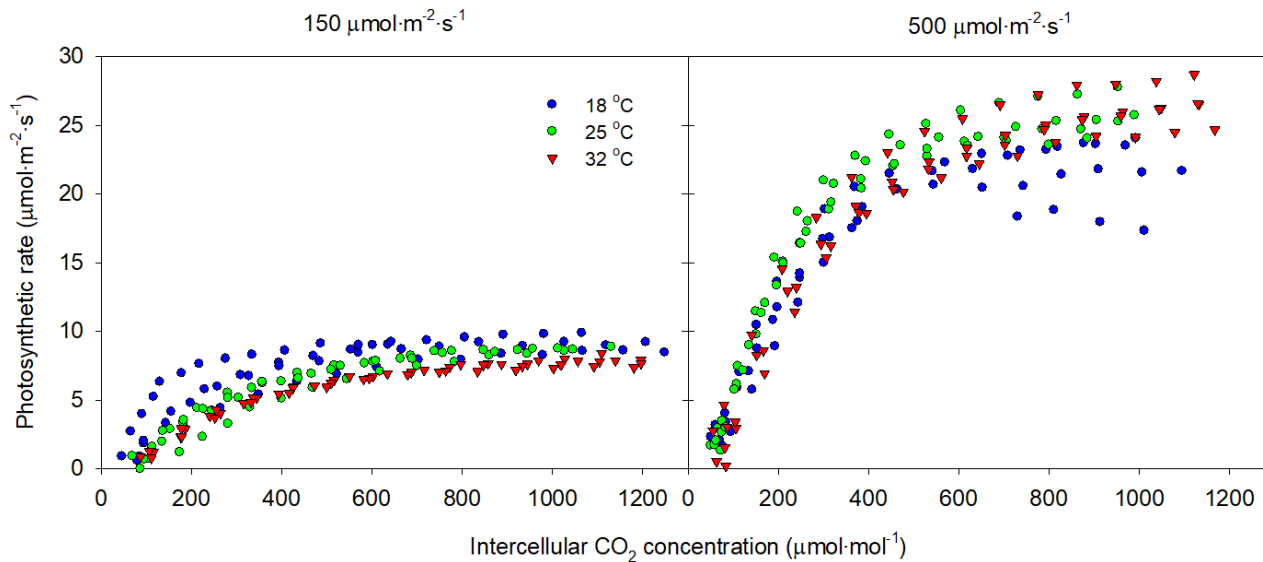


Figure 2.

A/C_i curves were measured at three temperature conditions (18, 25, and 32 °C) under low light (left) and high light (right), 150 or 800 µmol·m⁻²·s⁻¹, respectively. For each treatment, n = 4.

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If you would like to learn more about this application or speak with one of our experienced technical staff, please feel free to get in direct contact with us via any of the contact information listed below:

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