

A simple photosynthesis measurement device using a compact, low-cost microcomputer and CO₂ sensor

Leaf photosynthetic rate is a growth assessment indicator used in many contexts within the field of plant science. The assimilation chamber method is one of its measurement techniques, and commercially available portable measuring devices were first introduced approximately 40 years ago. Today, their successor models are the mainstream choice due to advantages such as superior measurement accuracy and speed. On the other hand, the high cost (ranging from several million to over 10 million yen, and subject to further increases due to social conditions and exchange rate fluctuations) is the primary concern preventing a wide range of users (researchers, producers, educators, etc.) from utilizing photosynthesis measurement devices.

We developed a prototype closed-system photosynthesis measurement system (hereinafter referred to as the "demo device") that incorporates an inexpensive CO₂ sensor into a custom-built assimilation chamber and is controlled and recorded by a small microcomputer (Fig. 1a,b). The demo device can be built inexpensively with material costs of approximately 30,000 yen. When the measurement performance of the demo device was compared to that of a standard unit using sugarcane leaves, a significant correlation between the measured values was observed in both cases: when light intensity was varied using artificial light sources in a temperature- and humidity-controlled room (Fig. 2a) and when multiple varieties were measured under natural outdoor light conditions (Fig. 2b). The accuracy of a simple linear regression model using the photosynthesis rate measurements from these devices was sufficiently high with low values of root mean square error under all conditions, highlighting the high measurement accuracy of the demo device.

Our results indicate that as photosynthesis measurements become more affordable and accessible, photosynthesis research will become more accessible to many researchers with limited budgets, thereby stimulating research in related fields. These results do not guarantee performance equivalent to that of the standard unit; it is recommended that the demo device and the standard unit be used for different purposes as appropriate. Since inexpensive CO₂ sensors may vary in performance and durability, it is necessary to verify their performance under atmospheric CO₂ conditions or known CO₂ concentrations as appropriate. To apply this system to the evaluation of multiple samples (high-throughput phenotyping), such as genetic resources or hybrid populations, improvements to the data recording system (e.g., from wired to wireless) and the measurement system (e.g., from closed to open) should be considered.

Authors: Takaragawa, H. [JIRCAS], Asahi, T., Mitsuoka, M., Taira, E., Kawamitsu, Y. [Univ. of the Ryukyus]

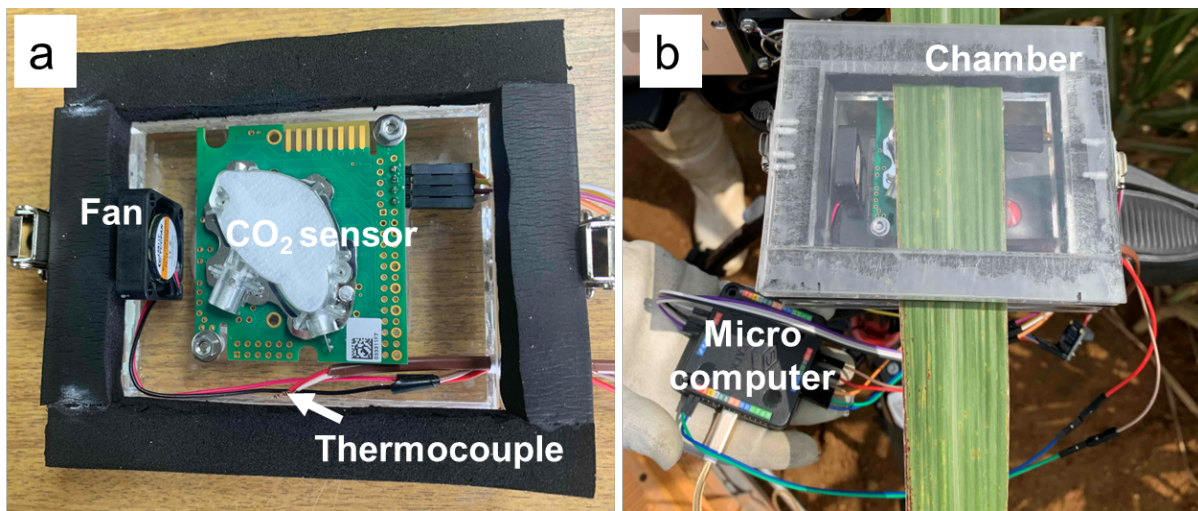


Fig. 1. Outline of demo device

The sensors inside the assimilation chamber (a) and the demo device during measurement (b) are shown. A CO₂ sensor, fan, and thermocouple are installed inside the assimilation chamber, and these are connected to an external microcontroller via jumper wires to drive them.

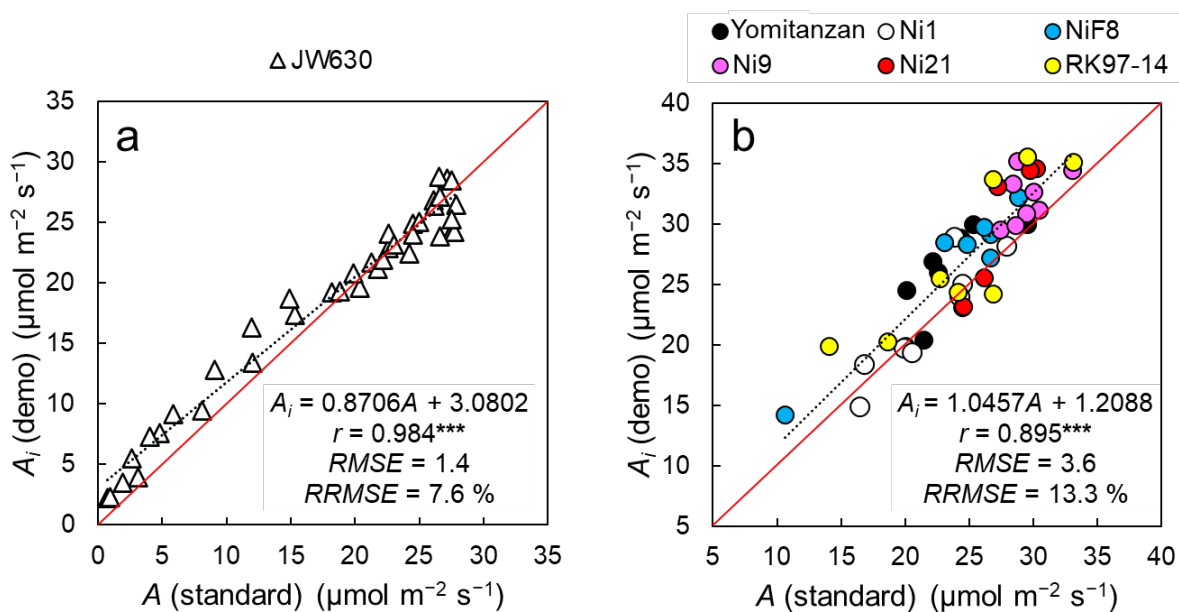


Fig. 2. Comparison of photosynthetic rates in sugarcane leaves measured using the demo device and a standard unit

A_i (demo device) and A (standard unit) represent the photosynthetic rates measured using the demo device and standard unit (with light-transmitting chamber), respectively (a: data obtained by varying light intensity using a single line in a temperature- and humidity-controlled glasshouse ($n=50$); b: data obtained using multiple varieties in a field environment ($n=45$)). The dashed lines represent the linear regression equations with A_i as the dependent variable and A as the independent variable. r denotes the correlation coefficient, and *** indicates that the correlation is significant at the 0.1% level. RMSE and RRMSE denote the root mean square error and relative root mean square error, respectively; lower values indicate higher accuracy of the regression equation. The solid red line represents $y = x$.

Reference: Takaragawa et al. (2025) *Photosynthesis Research* 163: 52. © Authors 2025

The figures are modified from Takaragawa et al. (2025).