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Automatic Air-Exchange Whole-Plant Carbon Sequestration Measurement System in Potted Native Taiwanese Plant Applications

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ABSTRACT

As the climate crisis accelerates, reliable data on the carbon-sequestration capacity of native plants are needed to guide nature-based mitigation strategies. Accurate, whole-plant assessments of carbon sequestration are crucial for identifying native species that can efficiently reduce atmospheric carbon dioxide, yet most plant physiology studies rely on costly instruments limited to leaf-level measurements. We therefore designed a low-cost, closed-chamber system that automatically refresh air to stabilize relative humidity in the chamber while records CO_2 concentrations in real time with readily available sensors. Bench tests on the potted *Peperomia japonica*, with each measurement cycle lasting three hours, showed the chamber's changes in CO_2 concentrations tracked a commercial LI-6800 portable photosynthesis system with a strong linear relationship ($R^2 > 0.97$), confirming both accuracy and stability. Under the test condition (photosynthetic photon flux density at 1070 μmol m^{-2} s^{-1} and air temperature at 25 °C), *P. japonica* assimilated CO_2 at approximately 0.40 mg m^{-2} s^{-1}, demonstrating the system's efficacy for precise whole-plant carbon-sink quantification. The prototype offers an affordable, scalable tool for screening the carbon sequestration potential of native Taiwanese plants in whole-plant and budget-constrained studies, and thus supports evidence-based species selection for climate-mitigation planting programs.

Keywords: Closed chamber, low-cost sensors, carbon sequestration, whole-plant gas exchange.

INTRODUCTION

Industrialization has accelerated greenhouse gas accumulation, with urban areas as major sources. Enhancing urban green space carbon sinks through native plants requires reliable whole-plant measurements. Commercial chambers are expensive and limited in environmental control, often causing elevated temperature and humidity that compromise plant physiology and data accuracy.

This study develops a low-cost whole-plant chamber with automatic ventilation, validated against advanced instruments to enable high-throughput screening and application of native plants for urban carbon sequestration.

MATERIALS AND METHODS

System architecture [Fig. 1]: Acrylic chamber with airtight seal; solenoid valves and pumps for gas exchange; CO_2 and temperature–humidity sensors inside and outside; growth lamps, fans, and quantum sensor. An embedded controller coordinates data logging and rule-based ventilation to stabilize relative humidity and background CO_2, preserving linear segments needed for flux estimation.

Measurement workflow: Two modes: *measurement* and *exchange*. Daytime (photosynthesis + respiration) and nighttime (respiration) measured separately. Soil respiration measured under identical conditions and subtracted to calculate whole-plant NCER(referred to as Eq. (1)):

$$P_{net} = P_{net.mornimg} + P_{net.night} - R_{humus.morning} - R_{humus.night} \tag{1}$$

where:

P_{net} = Whole-plant net CO_2 exchange rate (mg m^{-2} s^{-1})

$P_{net.mornimg}$ = Whole-plant net CO_2 exchange rate in the morning (mg m^{-2} s^{-1})

$P_{net.night}$ = Whole-plant net CO_2 exchange rate in the night (mg m^{-2} s^{-1})

$R_{humus.morning}$ = Soil net CO_2 exchange rate in the morning (mg m^{-2} s^{-1})

$R_{humus.night}$ = Soil net CO_2 exchange rate in the night (mg m^{-2} s^{-1})

Validation design: Five-inch potted *Peperomia japonica* under 25 °C, PPFD = 1,070 μmol m^{-2} s^{-1}. System benchmarked against LI-6800 (Li-Cor, USA) by comparing CO_2 trends, linearity, and NCER consistency.

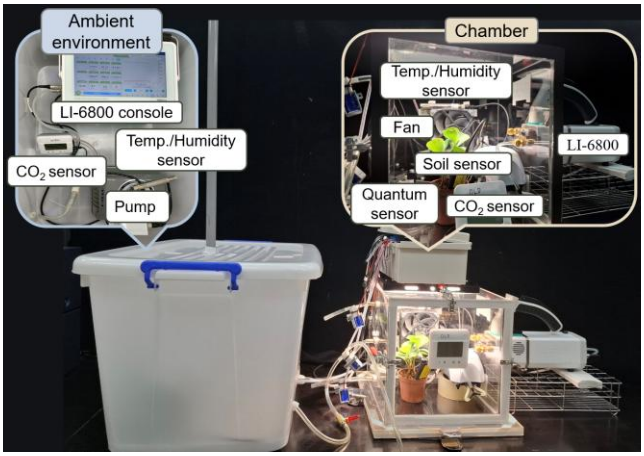

Fig1. Experimental setup diagram

RESULTS & DISCUSSION

Photosynthesis measurement of *Peperomia japonica*

The chamber and LI-6800 showed consistent CO_2 concentration trends with a strong linear relationship ($R^2 = 0.97$). The estimated NCER averages were comparable, with no significant statistical difference. Under the test conditions, *P. japonica* exhibited an NCER of approximately 0.40 mg m^{-2} s^{-1}, indicating that the system effectively captured actual carbon uptake and flux.

Measurement of Peperomia Respiration and Soil Respiration

Nighttime measurements showed consistent trends between the two instruments. Due to the low magnitude of fluxes, the data were susceptible to noise; similar results were observed for soil respiration. Overall, no significant differences were detected. However, using larger plants and extending measurement duration is recommended to improve the signal-to-noise ratio, and repeated measurements can help reduce uncertainty.

CONCLUSIONS

This study developed a low-cost, whole-plant chamber system with automated air exchange and validated its performance against the LI-6800 using potted *Piper japonica*. Under standardized conditions, the system yielded NCER values not statistically different from those of the commercial instrument, demonstrating its accuracy and stability. Future work will employ larger pots to improve testing conditions and expand datasets, further validating and optimizing system performance. This platform offers a cost-effective and reliable tool for monitoring plant carbon cycling in ecological studies.

REFERENCES

S. Lahoti, A. Lahoti, R. Kumar Joshi, O. Saito. 2020. Vegetation structure, species composition, and carbon sink potential of urban green spaces in nagpur city. In India. *Land.* 9(4).

S. Gagnon, E. L'Hérault, M. Lemay, M. Allard. 2016. New low-cost automated system of closed chambers to measure greenhouse gas emissions from the tundra. In *Agricultural and Forest Meteorology*, 228-229, 29-41.

M. Ladrón De Guevara, R. Lázaro, J. L. Quero, S. Chamizo, F. Domingo. 2015. Easy-to-make portable chamber for in situ CO_2 exchange measurements on biological soil crusts. In *Photosynthetica.*, 53, 72-84.