Construction of a Light Emitting Diode Chamber for Measurement of Gas Exchange for the Plant Ecosystem

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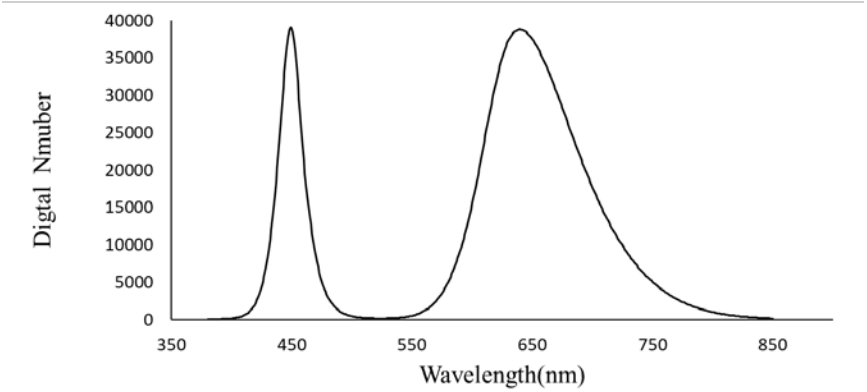
Introduction

Canopy photosynthetic CO_2 uptake rates are positively correlated to crop yields (Wells et al., 1982; Zelitch, 1982). A closed canopy photosynthetic measurement system has been widely used to determine gas exchanges in the plant ecosystem under the solar radiation condition. It is challenging to measure stable canopy fluxes in the field due to fluctuated solar radiation conditions in nature. With our best knowledge, there have been no attempts to make an effective and rapid system for measurement of quantitative gas exchange in plant canopy using a stable synthetic light source. To overcome this problem, we constructed a new chamber system with Light Emitting Diodes (LEDs) to measure canopy fluxes. In the current study, we describes the system design, application, and evaluation of an LEDs chamber.

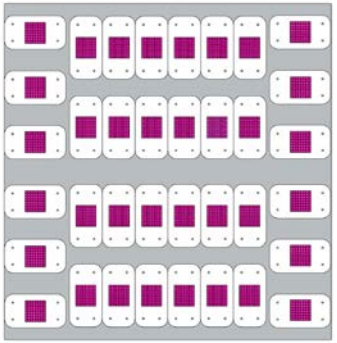
Construction of the LEDs chamber system

[LED panel]

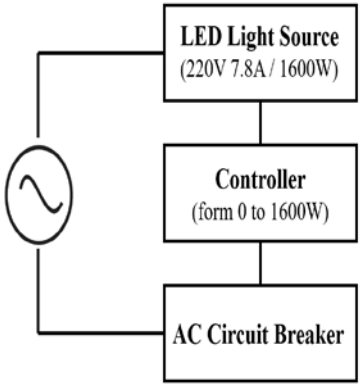
- The power of the LEDs panel : 1,600 W
- LEDs wavelengths used : 450 nm and 660 nm
- Light intensity : 0 to 8,000 µmol
  - ✓ The intensity of the LED panel was corrected using a quantum sensor from Li-Cor, Inc. (Lincoln, NE, US)



LED Spectrum



LED Array



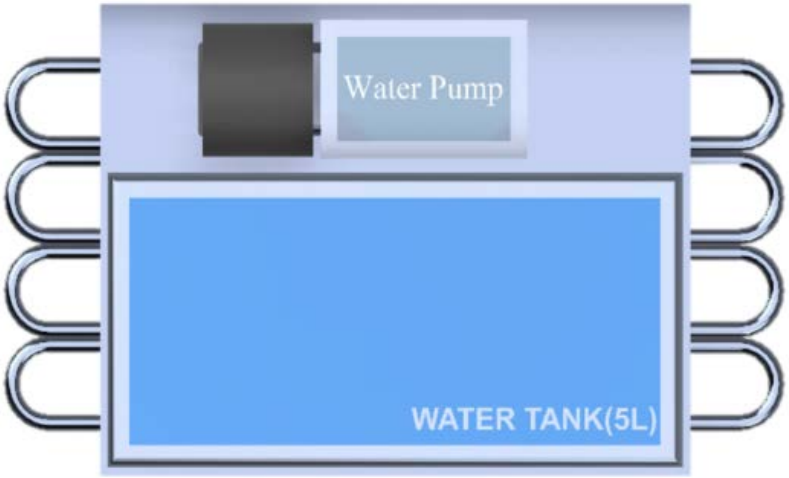
Diagram

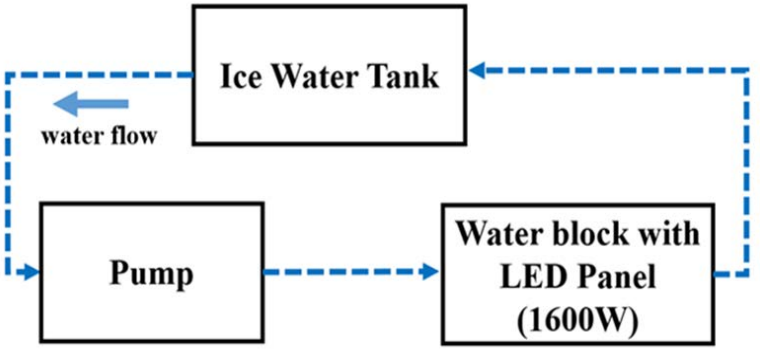
Construction of the LEDs chamber system continued

[Water cooling structure]

- This structure was fabricated to cool the heat generated in the LEDs panel.
  - ✓ Owing to the water cooling design, the heat generated by the LEDs panel does not affect the temperature inside the chamber.

- The water cooling structure comprised a water pump, water blocks, and a water tank.

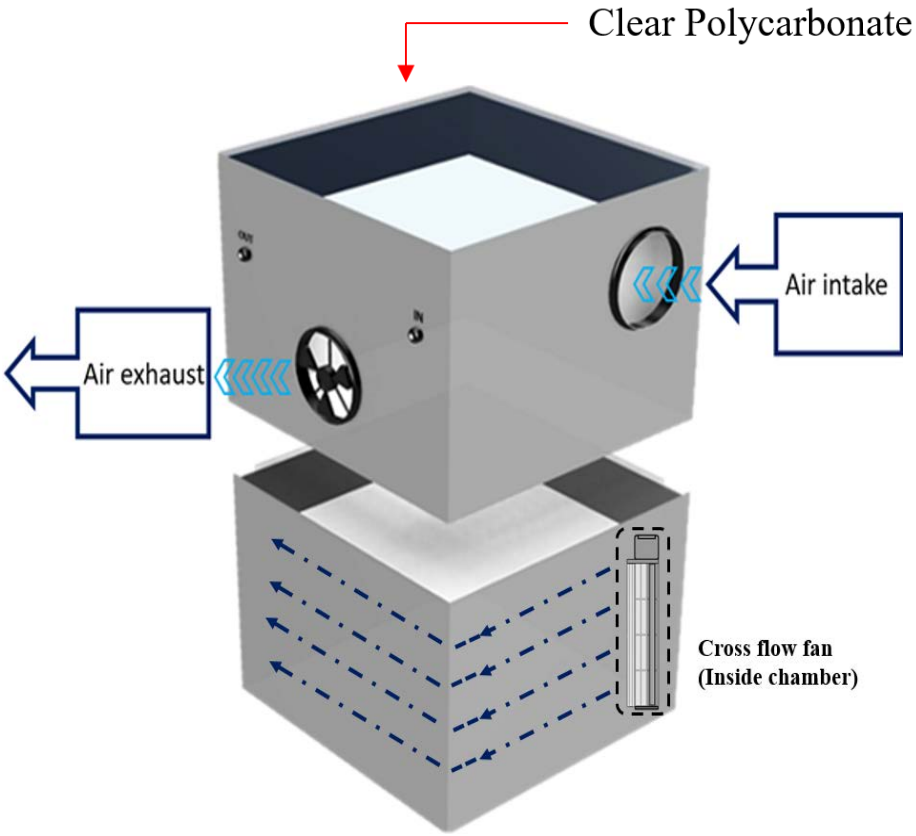




Construction of the LEDs chamber system continued

[Formulation of a closed chamber scheme]

- A semi-automatic ventilation structure was assembled with making intake and exhaust holes in the closed chamber system.
- An extendable chamber design was also applied to the chamber system (39.2cm x 39.2cm x extendable height).
- The air in the closed chamber system was circulated using a cross flow fan.
- The upper part of the system was made of a clear polycarbonate for incident light of the LEDs.



Measurement methods of canopy gas exchange

- CO_2 concentrations inside the chamber system were measured with an infrared gas analyzer (LI-850) from Li-Cor, Inc. (Lincoln, NE, USA).

- In addition to CO_2 concentrations, other micro-meteorological factors including evapotranspiration and temperature were measured.

- Temperatures inside the chamber were maintained as close as the outside temperatures during the measurements at all light intensity conditions from 0 to 3,100 µmol.

(LI-850, Licor, USA)

(Field measurement of canopy CO_2)

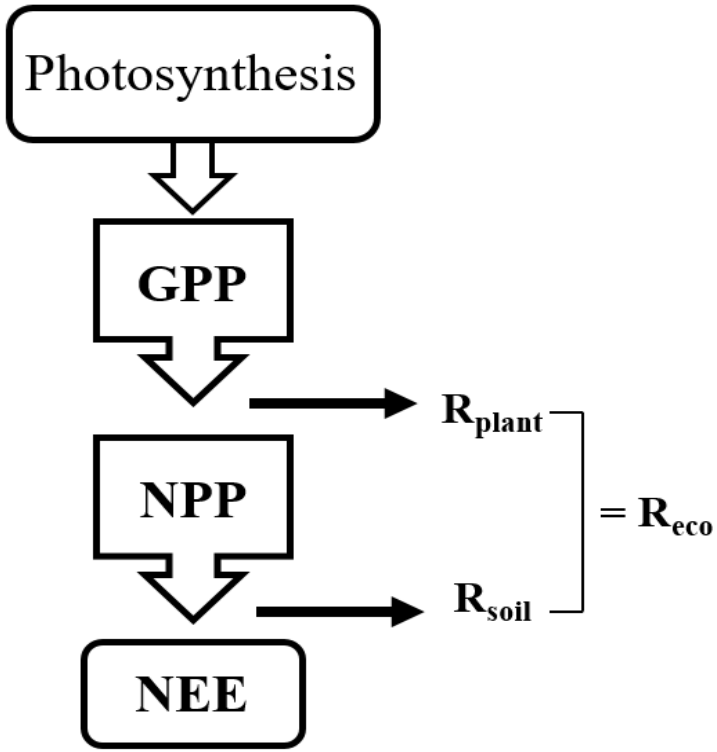
Measured methods of the gas exchange continued

- Determination of CO_2 fluxes (Flessa *et al*., 1998)

  $$F_{CO2} = K_{CO2}\,(273*T^{-1})\,(V*A^{-1})\,(dc*dt^{-1})$$

- GPP calculation (Adiko *et al*., 2006)

  $$GPP = -NEE + R_{eco}$$



Measured results of the gas exchange system

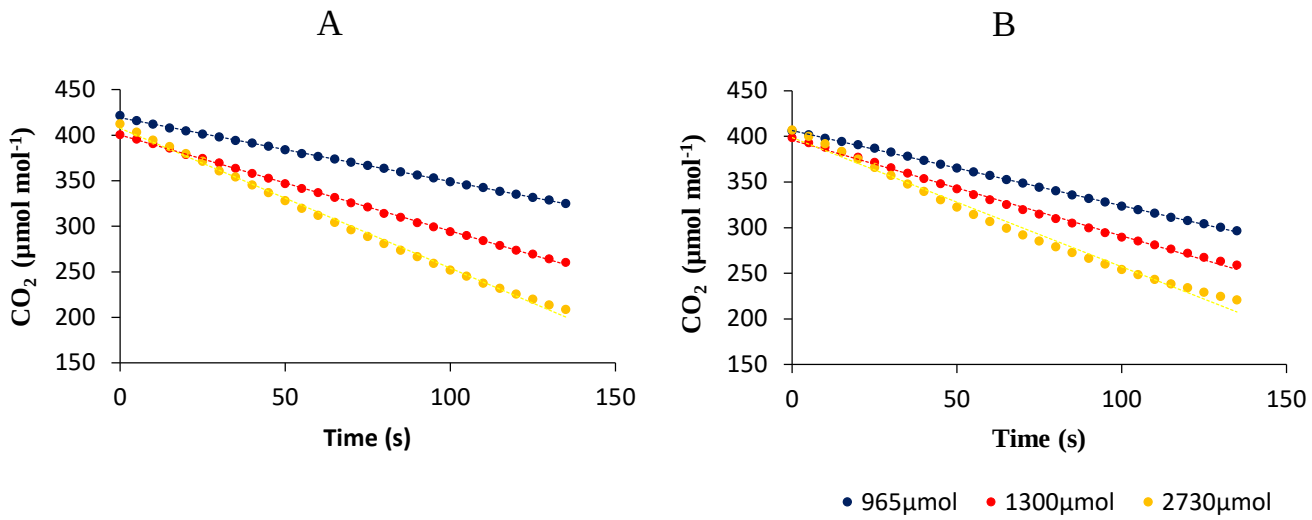


Figure 1. CO_2 uptake rates at different intensity regimes of photosynthetically active radiation (PAR) for wheat (A) and barley (B).

- When the LED chamber was closed, the initial CO_2 concentration in the chamber system gradually decreased.

- Data logger recorded CO_2 concentration in the chamber every 5 seconds.

Measured results of the gas exchange system

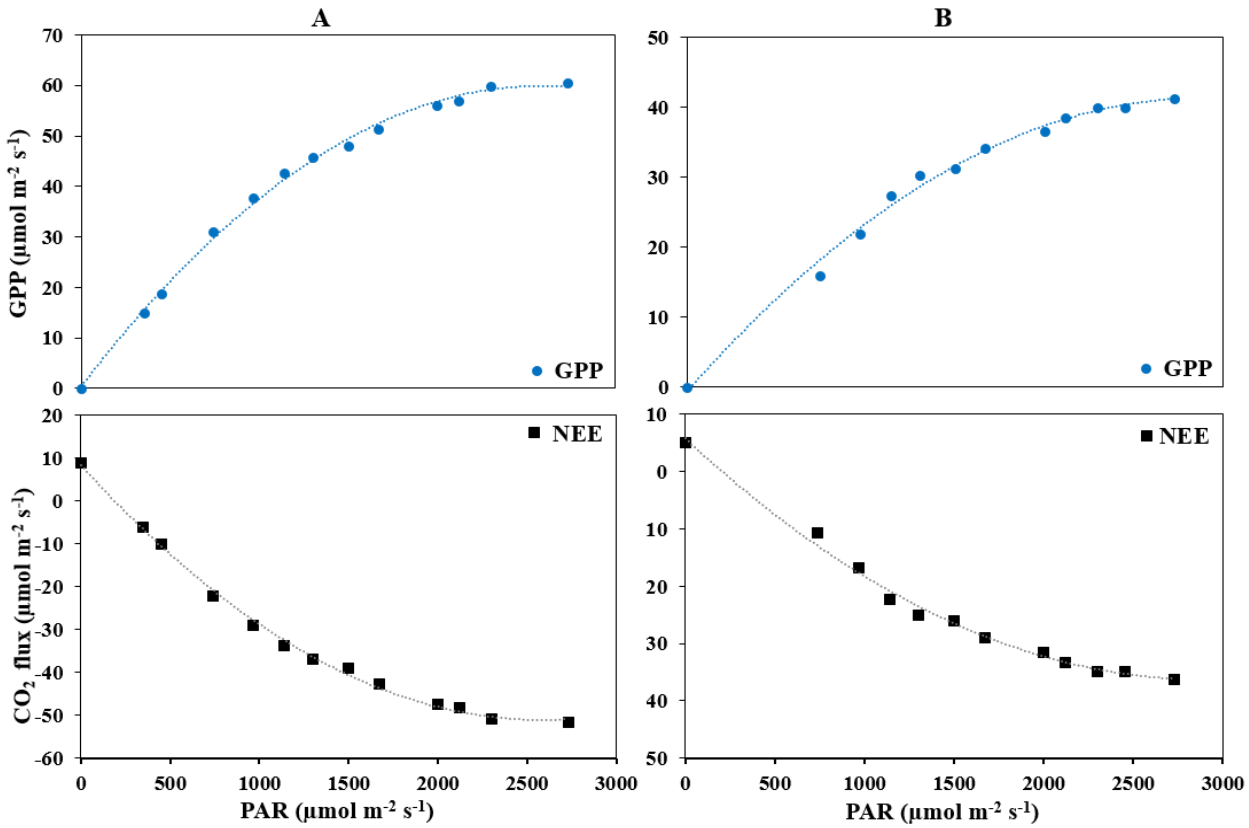


Figure 2. Changes in gross primary production (GPP) and net ecosystem exchange (NEE) in relation to photosynthetically active radiation (PAR) at the heading stage for wheat (A) and barley (B).

Summary & Conclusion

- In this study, we successfully constructed, implemented, and evaluated a new measurement system of canopy fluxes using LEDs as a light source. The developed chamber system was composed of an extendable chamber, a 1600W LED panel, a quantum sensor, a water pump and water block for cooling, and an infrared gas analyzer.
- The LED chamber system can measure quantitative gas exchanges in plant canopies.
- We assume that the novel LED chamber system is a productive approach to determine canopy gas exchanges in the plant ecosystem in comparison with any other closed chamber systems.
- The measurement system can contribute to practical assessment of crop productivity as well as scientific advancement in plant ecophysiology.