Considerations for Accurate Whole Plant Photosynthesis Measurement

An understanding of a plant's response to the environment is important for the prediction of its growth and development. Because any organ that contains chloroplasts in plants can contribute to plant production and all plant tissue respires constantly, carbon exchange rate (CER) measurements are used to quantify the effects of environmental changes on plant productivity and determine the final yield. Whole plant CER measurements have been better predictors of final yields more than measurements obtained from single leaf CER. Most whole plant CER measurement instruments are custom designed and constructed. The objective of this study was to review designs of assimilation chambers for whole canopy CER measurements and to compile a set of operational guidelines to improve their measurement accuracy.

Whole plant CER systems can be closed, semi-closed, or open systems. Closed systems measure photosynthesis as the CO_2 depletion rate or respiration as an increase in CO_2. They are useful for short-term, transient response measurements. Disadvantages to these systems include the inability to provide true steady-state measurements and the difficulty in constructing an assimilation chamber with zero leakage. Semi-closed systems measure photosynthesis and respiration as the amount of CO_2 added or removed to maintain a CO_2 set point within the chamber. They are commonly used for diurnal changes, but like closed systems, chamber leakage is an issue.

Open systems measure the CO_2 differential in supply air versus chamber air (Figure 1). Their design eliminates leakage issues and makes long-term monitoring possible. Common operational factors to be aware of in open systems include maintaining positive chamber pressure, acquiring accurate measurements of air flow and CO_2 differential over sufficient ranges, understanding the effects of water vapor on analyzer measurements, and maintaining appropriate air speed around the canopy (Table 1). Biological considerations, such as soil microbial communities and the effects of irrigation on photosynthesis and respiration, must also be evaluated.

Two-step evaluations are recommended when evaluating performance of a whole canopy carbon exchange system. CER measurement accuracy may be verified by comparing measured CER against the known amount of CO_2 evolution derived from $NAHCO_3$ and dilute acid. Net photosynthesis may be verified by comparing predicted carbon gain with carbon gain determined by a destructive method, such as a C-H-N analysis.

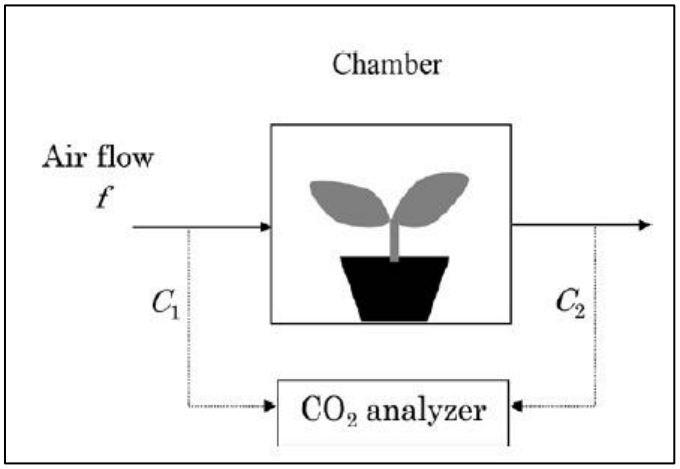

Figure 1. Schematic diagram of an open photosynthesis measurement system. f is air mass flow rate through the chamber [mol s^{-1}], C_1 and C_2 are CO_2 concentrations at the inlet and the outlet [µmol mol^{-1}], respectively. A is total leaf area of the canopy, or surface area of the chamber [m^2].

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Table 1. Minimum guidelines of environmental control consideration of various open systems.

References	Mentioned factors			
	Air speed around the plant	Pressurized chamber to prevent inward air leakage	To adjust the Air flow rate	Humidity control
Bate and Canvin (1971)	Not reported	Yes	To maintain CO_2 differential less than 30 μmol mol^{-1}	cooling coil
Bugbee (1992)	0.8 m s^{-1}	Yes	Not reported	desiccant
Corelli-Grappadelli and Magnanini (1993)	Not reported	Yes	To regulate temperature in the chamber	Not reported
Miller et al. (1996)	Not reported	Yes	To regulate temperature in the chamber	Not reported
van Iersel and Bugbee (2000)	Not reported	Yes	To maintain CO_2 concentration in the chamber	cooling coil

Takahashi, N., P.P. Ling, J.M. Frantz. 2008. Consideration for accurate whole plant photosynthesis measurement. Environ. Control Biol. 46:71-81.