Minimization of diffusion error in measured photosynthetic gas-exchange parameters with the LI-COR LI-6800 photosynthesis system

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Introduction

The LI-6800 is a new portable photosynthesis system from LI-COR, and one of its design goals was to reduce system leaks that allow diffusion to occur. In gas exchange systems, both bulk flow and diffusion leaks can result in errors in calculated parameters such as assimilation (A) and transpiration (E) by impacting the fundamental mass balance upon which these parameters are based. These errors are then propagated into errors in other physiologically important parameters such as stomatal conductance (g_{sw}), intercellular CO_2 concentration (C_i), maximum Rubisco carboxylase activity (V_{cmax}), and J_{max}, the maximum electron transport rate (Flexas et al. 2007; Long and Bernacchi 2003; Rodeghiero et al. 2007). Several additive factors, including leaf morphology, magnitude of leaf CO_2 and H_2O fluxes, enclosed leaf area, gasket and other material properties, and concentration gradients across gaskets determine the total impact of leaks on system performance (Long and Bernacchi 2003; Rodeghiero et al. 2007). Experimental methods exist for estimating the magnitude of leaks which allows data to be post-corrected (LI-COR 2011; Rodeghiero et al. 2007). Here, we report some preliminary data from the LI-6800 portable photosynthesis system that demonstrates improved leakage characteristics when compared with the LI-6400XT.

Materials and Methods

Four LI-6400XTs and four pilot LI-6800s were tested for diffusion leak characteristics. Data was collected using chambers with an area of 6 cm^2, the standard 2x3 chamber for the LI-6400 and the LI-6800 Multiphase Flash™ fluorometer chamber. All eight instruments were placed into a Percival Scientific AR-41L2 growth chamber (setup shown at right), along with an LI-820 to monitor ambient CO_2 concentrations, which were controlled at ~1950 ppm. Instruments were supplied with 1.5 LPM of 0 ppm CO_2 gas that was plumbed into each instrument just upstream of the reference and sample air stream flow split. Instrument sample chamber flow rates were controlled from 100 to 700 µmol s^{-1}. The experiment was repeated after removal of gaskets and replacement with aluminum tape to determine relative contribution of the gaskets to total diffusion. An additional experiment was conducted in the laboratory where empty chamber CO_2 response curves were performed using six of the eight instruments used in the prior experiments. AutoPrograms were set to log data every 120 seconds. In the LI-6400, data was collected for the 2x3 chamber, while in the LI-6800, both the fluorometer and the 3x3 chambers were tested. Ambient CO_2 concentration was monitored throughout with an LI-820.

Results

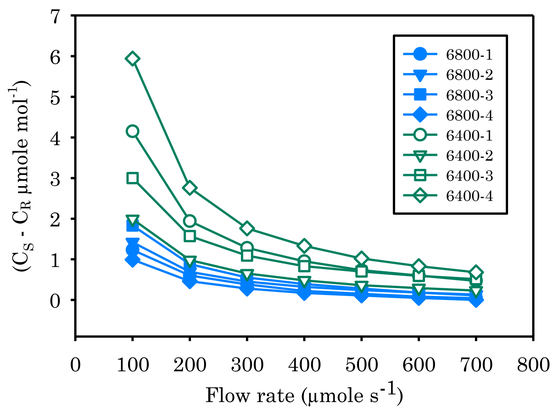

Fig. 1: ΔCO_2 vs sample flow rate. The analyzers were supplied ultra-pure 0 ppm CO_2 air and ambient CO_2 was ~1950 ppm.

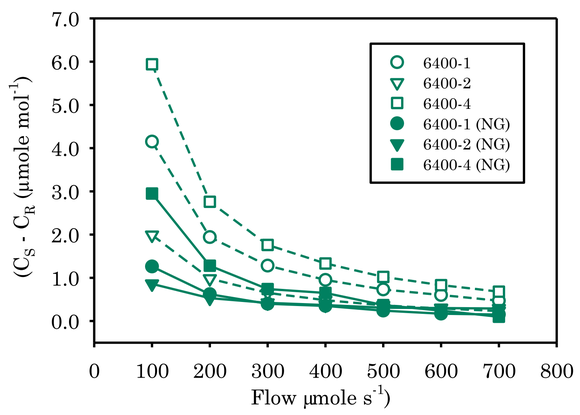

Fig. 3: ΔCO_2 vs sample flow rate in the LI-6400 with gaskets and with gaskets removed (NG) and covered by aluminum tape. The system without gaskets reduces total apparent diffusion by ~50%.

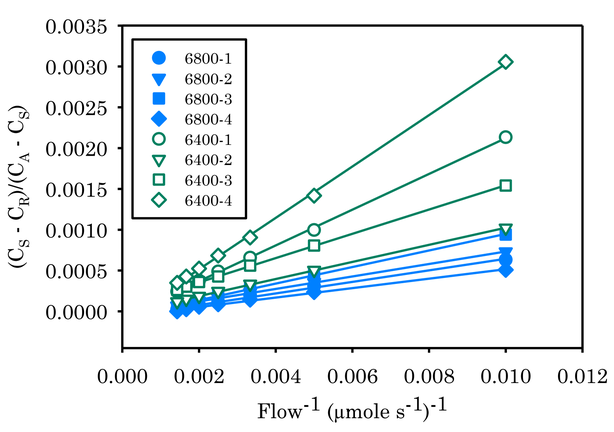

Fig. 2: ΔCO_2 normalized to C_a vs 1/flow rate. Leak rate coefficients (k) range from 0.105 to 0.315 in the LI-6400, and from 0.071 to 0.101 in the LI-6800. Prior testing of the LI-6400 resulted in k = 0.46 in the LI-6400 (LI-COR 2011).

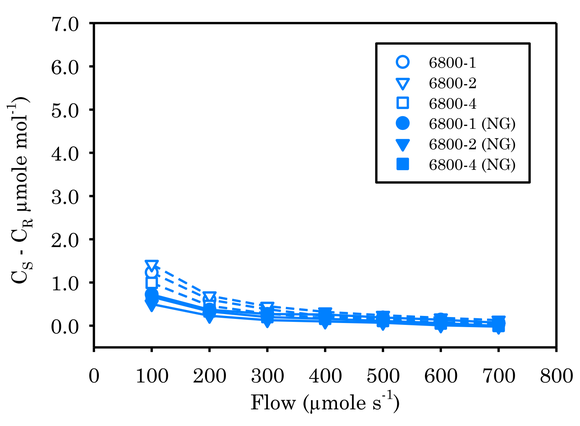

Fig. 4: ΔCO_2 vs sample flow rate in the LI-6800 with gaskets and with gaskets removed (NG) and covered by aluminum tape. The system without gaskets reduces total apparent diffusion by ~50%.

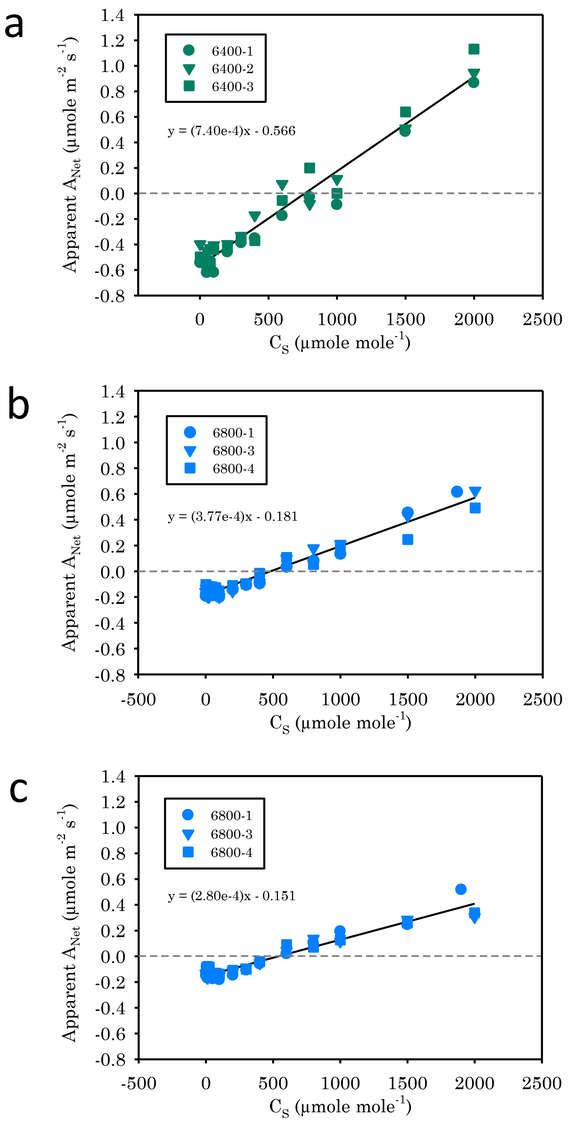

Fig. 5: Empty chamber CO_2 response curves in a) LI-6400 with standard 2x3 chamber; b) LI-6800 fluorometer; and c) LI-6800 3x3 chamber. Ambient CO_2 was ~500-600 ppm.

Conclusions

- Newer-production LI-6400XTs exhibit much lower leak rate coefficients (k) than reported previously with an average k = 0.20 (this study) vs. k = 0.46 (LI-COR 2011).
- The LI-6800 exhibited a lower average leak rate coefficient (k = 0.077± 0.018) and less variability than the tested LI-6400XTs (k = 0.20 ± 0.092).
- In both systems, ~50% of the total apparent leakage is due to leaf chamber gaskets.

References

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