Measurement of Leaf Gas Exchange Based on a New Single-Step CO_2 Response Method for Rapidly Obtaining A vs. C_i Curves

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Introduction

- Ramping of CO_2 either up or down, and recording data once stabilized is a common technique used to develop A vs. C_i curves.
- Researchers collecting A vs. C_i curves may be limited by additional steps to validate and collect accurate data, including:
  - Time-intensive (empty) chamber calibration prior to data collection.
  - Post-processing of data after collection.
- We tested a novel, single-step CO_2 response ($SSCO_2R^{TM}$) to eliminate extra calibration and data processing steps. The validation method was performed on leaves of tomato plants in two growing conditions.

Materials & Methods

- A vs. C_i data was captured for tomato leaves under field and growth chamber conditions using traditional steady-state methods and the single-step CO_2 response method (described below).
  - Both methods were tested on the same leaves for two tomato cultivars in the field, and three tomato cultivars in growth chambers.
  - All data was collected using the Ciras-4 Portable Photosynthesis System.

The $SSCO_2R^{TM}$ Method:

For the $SSCO_2R^{TM}$ method, an adjustable volume plunger was inserted into the reference air line to reduce measurement differences in CO_2 between reference and analysis infrared gas exchange analyzers (IRGA).

Data collection:

- A leaf cuvette was enclosed on a fully expanded tomato leaf.
- Steady state data collection was conducted for eight CO_2 concentrations between 100 and 700 µmol mol^{-1}. Data was post-processed and an empty chamber ramp was conducted before collection on the leaf.
- $SSCO_2R^{TM}$ data collection was conducted every one second during CO_2 ramping from 100 to 700 µmol mol^{-1} at a rate of 200 µmol mol^{-1} min^{-1}.

Results

Using the new single-step CO_2 response method, complete A vs. C_i curves can be obtained for leaves of C_3 species in about 5 minutes, with no post-processing of data required.

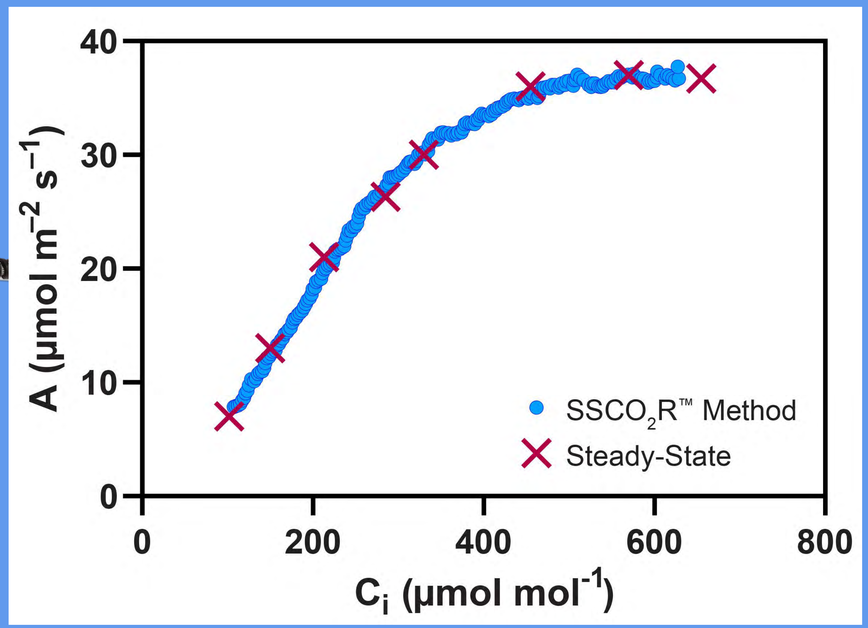

Figure 1. **Relationships between CO_2 assimilation rate (A) and internal CO_2 (C_i) for a tomato leaf measured at 22 °C and 1500 mmol m^{-2} s^{-1} PPFD near midday in the field—either under steady-state CO_2 conditions or during an upward ramping of CO_2—at a rate of 200 mmol mol^{-1} min^{-1}, using the $SSCO_2R^{TM}$ Method.**

Results (continued)

- Traditional methods using steady-state determination of A vs C_i was adequate to produce a curve for all tested cultivars in field and growth chamber conditions with eight total data points per curve. Collection of data (not including data processing and device setup) was roughly 30 minutes for each curve.
- The $SSCO_2R^{TM}$ method was able to produce A vs C_i curves with a high resolution of 300 data points per curve. Collection of data (not including device setup) was roughly five minutes for each curve.

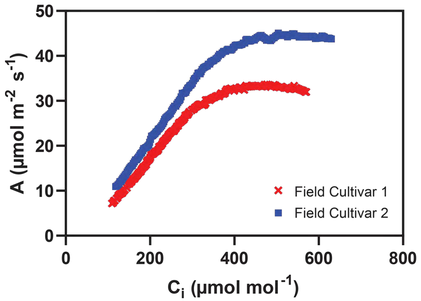

Figure 2. CO_2 assimilation rate (A) and internal CO_2 (C_i) for leaves of two different cultivars of tomato measured at 22 °C, and 1500 mmol m^{-2} s^{-1} PPFD within a few minutes of each other, near midday, in the field. Curves were determined using the $SSCO_2R^{TM}$ Method with CO_2 increasing at a rate of 200 µmol mol^{-1} min^{-1}.

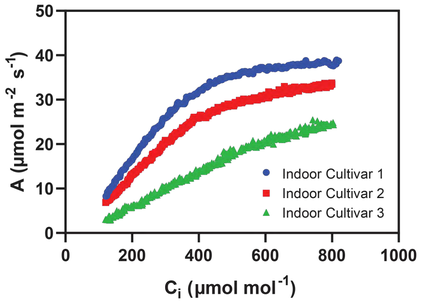

Figure 3. CO_2 assimilation rate (A) and internal CO_2 (C_i) for leaves of three different lines of tomatoes grown in a growth chamber at 22 °C, a PPFD of 400 mmol m^{-2} s^{-1} for 12 hours per day, and measured at 22 °C, and 1500 mmol m^{-2} s^{-1} PPFD. Curves were determined using the $SSCO_2R^{TM}$ Method with CO_2 increasing at a rate of 200 µmol mol^{-1} min^{-1}.

Photosynthesis model parameters for tomato curves

Variable	Steady-state	$SSCO_2R^{TM}$	Field Cultivar 1	Field Cultivar 2	Indoor Cultivar 1	Indoor Cultivar 2	Indoor Cultivar 3
V_{cmax}	124	128	98	108	81	71	56
J_{max}	205	209	189	220	174	161	120
TPU	10.1	9.9	9	12	10	9.5	6.1
Rd	3.8	4.3	3.3	2.9	2.3	3	3.6
g_m	3.1	3.2	7.5	7	7	8.2	8

Table 1. Parameters of the Farquhar, von Caemmerer, Berry photosynthesis model derived from the A vs. C_i curves of tomato leaves (Fig. 1-3) in this study. Units are mmol m^{-2} s^{-1} for V_{Cmax}, J_{max}, TPU, and Rd, and µmol m^{-2} s^{-1} Pa^{-1} for g_m. For all measurements, leaf temperature was 22 °C, and PPFD was 1500 mmol m^{-2} s^{-1}.

Conclusion

- Using the new single-step CO_2 response method, complete A vs. C_i curves can be obtained for leaves of C_3 species in approximately five minutes with no post-processing of data required.
- Traditional methods for determining A vs C_i curves took six times longer than the $SSCO_2R^{TM}$ method.
- The $SSCO_2R^{TM}$ method can reduce data collection time, affording researchers more time to take measurements without the need for data validation steps after collection.