An Inter-comparison of Three Commercial Porometers

L. Bissey[1], D. Cobos[2], C. Campbell[2]

1. School of Earth and Environmental Science, Washington State University, 2. Decagon Devices, Inc.

Introduction

Stomatal conductance regulates the rates of several necessary processes in plants including transpiration, carbon dioxide assimilation, and respiration. Both steady state and dynamic porometers are currently used to measure stomatal conductance. However, few tests or measurements have been performed to compare the results obtained with the various porometers. It is important for scientists to understand the performance of each porometer in order to compare stomatal conductance data gathered from various models. In this study, we focused on three commercially available porometers: the AP-4 (Delta-T Devices, Cambridge, UK), the SC-1 (Decagon Devices, Pullman, WA), and the LI-1600 (Li-Cor, Lincoln, NE). The objective of this study was to understand the relationship between the stomatal conductance data gathered with the different instruments

Methods

Instrument Comparison with Standards

- Vapor conductance was measured using six standards:
  1. 1-ply Gortex $_{\text{®}}$ (avg. vapor conductance 55.71 mmol/m²s)
  2. 3-ply Gortex $_{\text{®}}$ (avg. vapor conductance 79.60 mmol/m²s)
  3. 2-ply Gortex $_{\text{®}}$ (avg. vapor conductance 91.36 mmol/m²s)
  4. Thick porous Teflon $_{\text{®}}$ (avg. vapor conductance 164.39 mmol/m²s)
  5. Thin porous Teflon $_{\text{®}}$ (avg. vapor conductance 465. 01 mmol/m²s)
- Measurements were performed in lab conditions to determine instrument differences under controlled conditions

Instrument Comparison with Leaves

- Stomatal conductance was measured on approximately 200 leaves in a field setting
- Changes in environmental conditions were minimized by taking measurements with the three porometers on similar locations of each leaf in rapid succession (instruments used in random order)
- Porometers were factory calibrated within 60 days of measurements

Explanation of Errors

- Physiological Variability- measured spatial variability of stomatal conductance on a leaf using all three instruments
- Wind effects-measured standards in wind tunnel to examine instrument changes due to effects of wind that were seen in the field

Data Interpretation

- Stomatal conductance data were normalized using natural-log transformation
- Paired t-test was used to examine the confidence intervals of the difference between instruments using data collected from leaves

Results

Standards and Leaves Comparison

- SC-1 generally measures slightly lower conductance readings than the AP-4
- Both the AP-4 (Fig 1, 2-b) and the SC-1 (Fig 1, 2-a) give conductance readings above that of the LI-1600
- High conductance values may incorporate more measurement error that low conductance values.
  - * not enough high conductance values are available to make any statistical conclusions

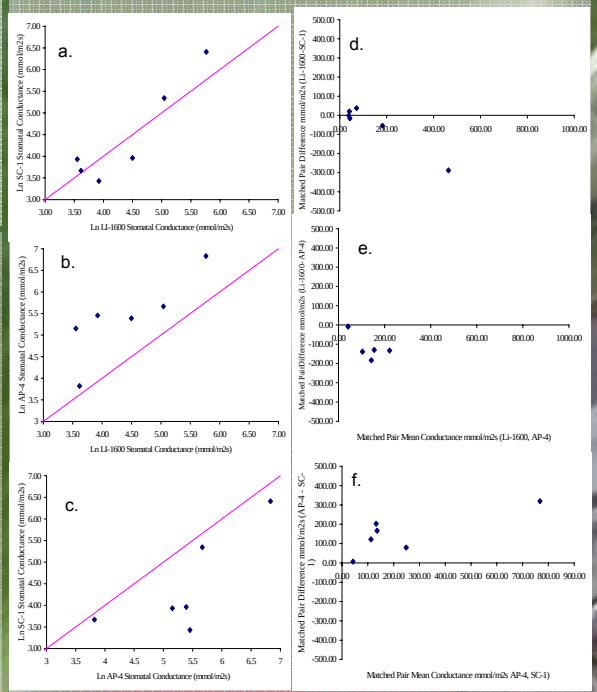

Figure 1. Correlation plots containing one-to-one lines of the regression of the natural log of the stomatal conductance data obtained by measuring standards using each instrument are shown on the left while corresponding plots showing matched pair stomatal conductance means and matched pair stomatal conductance differences for each instrument are shown on the right. Plots a and d compare the LI-1600 and the SC-1, plots b and e compare the LI-1600 with the AP-4, and plots c and f compare the AP-4 with the SC-1.

Results (contd.)

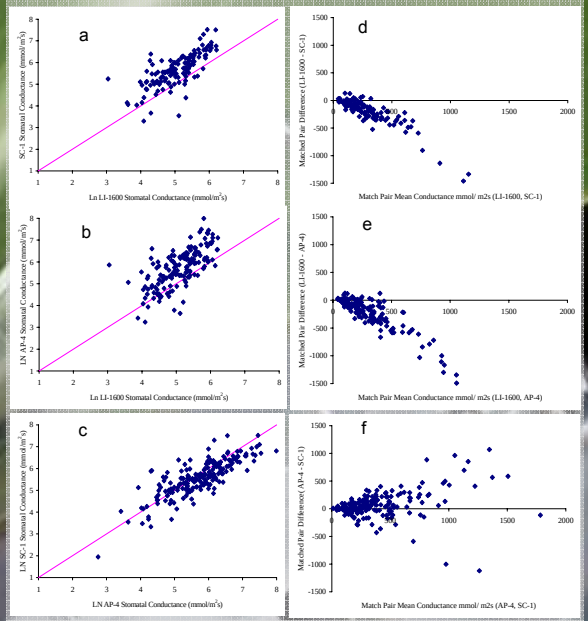

Figure 2. Correlation plots containing one-to-one lines of the regression of the natural log of the stomatal conductances obtained by measuring leaves using each instrument are shown on the left while corresponding plots showing matched pair stomatal conductance means and matched pair stomatal conductance differences for each instrument are shown on the right. Plots a and d compare the LI-1600 and the SC-1, plots b and e compare the LI-1600 with the AP-4, and plots c and f compare the AP-4 with the SC-1.

Table 1. Results from paired t-test (H_0: μ_D=0, α=0.05) showing the agreement between the natural log transformed stomatal conductance data obtained by the LI-1600, the SC-1, and the AP-4. Data were obtained in field conditions with paired samples having identical environmental conditions. Statistics on the non log transformed data are also included.

Instruments	Sample size (N)	Average Difference	Standard Deviation from the Mean	Standard Error from the Mean	95% Confidence Interval	P-value of T-test
LI-1600 - SC-1	129	-0.61	0.52	0.05	(-0.70, -0.52)	<0.005
LI-1600 - AP-4	155	-0.62	0.65	0.05	(-0.72, 0.52)	<0.005
AP-4 - SC-1	198	0.14	0.51	0.04	(0.07, 0.02)	<0.005
LI-1600 - SC-1*	129	-192	235	20.7		
LI-1600 - AP-4*	155	-241	350	28.1		
AP-4 - SC-1*	198	79	279	19.8		

* Values are descriptive statistics only.

Results (contd.)

Explanation of Error

- Significant spatial variability is present over the leaf surface (Figure 3)
- Wind showed no effects on conductance measurements for any instrument (data not shown)

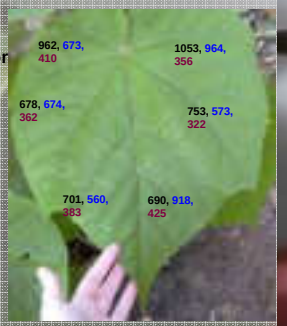

Figure 3. Example data showing leaf-level stomatal conductance variability. Numbers in black, blue, and purple are conductance data obtained using the AP-4, SC-1, and LI-1600 respectively. Data from different instruments were collected at different times and should not be compared among porometers.

Conclusions

1) All instruments show significant systematic differences in measured stomatal conductance at the α=0.05 level. However, these differences do not invalidate comparisons between conductance measurements between the three porometers.

2) All three instruments *appear* to have poorer agreement at high conductance values as shown in Figures 1.2 d, e, and f. However, there are not enough data at high conductance values to statistically validate these conclusions.

3) The LI-1600 generally reads lower than the other two porometers; especially at high conductivity values. Similar results have been found in other research (Delta T Devices, 2006).

4) The AP-4 and the SC-1 agree better than either of the two agree with the LI-1600.

5) Considerable spatial variability in conductance over the surface of single leaf and changing environmental conditions likely cause scatter in the intercomparison data. These errors can be minimized in practical application through the use of replicated measurements.

6) Results suggest that measurements should be comparable among the AP-4 and SC-1 at all conductance levels. The LI-1600 tends to measure lower conductances than the other two porometers, especially at higher conductances. This should be corrected for if results obtained by the two instruments are to be compared.

Reference

Delta T devices. Draft Leaf Porometer (SC-1) Evaluation. Unpublished manuscript. October 2006.

Doug Cobos, Decagon Devices
(509) 332-2756
doug@decagon.com