Supplementary Material

$\delta^{18}O$ accuracy and precision

Assessing the accuracy of our results is challenging, because no independently determined values were taken to compare with our calculated O_2. Therefore, we compare observed and expected changes in the $\delta^{18}O$ of O_2, and the O_2/N_2 ratio, in the dark. At zero irradiance, the change in $\delta^{18}O$ of O_2 must be zero (no addition of labeled photosynthetic O_2). Also, the change in O_2 concentration should be the opposite of the change in CO_2. This assumes a respiratory quotient, RQ=1, which we do not independently know. However, since the CO_2 change is small, the difference between the O_2 and CO_2 changes must be small even if RQ departs significantly from 1.00.

At zero irradiance, when the $\delta^{18}O$ of leaf water was labeled to ~8500‰ and exposed to air with 21% O_2, the difference in $\delta^{18}O$ of outgoing and incoming air was 0.013‰ ± 0.025‰ (1 SD, n=3) in the dark. For reference, if outgoing air has a $\delta^{18}O$ of O_2 1‰ higher than that of incoming air, gross O_2 production is of order 3 μmol O_2 m^{-2} sec^{-1}. When air with 2% O_2 is admitted to the chamber, the $\delta^{18}O$ of O_2 changes by -0.003‰ ± 0.053‰ (n=3). Under these conditions, a change in $\delta^{18}O$ of O_2 of 1‰ corresponds to an increase of 0.3 μmol O_2 m^{-2} sec^{-1}. Therefore, analytical errors in the measurement of gross production are very small.

In the same 6 experiments (all in the dark; 3 with 21% O_2 and 3 with 2% O_2), we measured the change in O_2/N_2 and CO_2 as air passes through the chamber. We expect O_2 changes to be close to the negative of CO_2 changes (exactly the same if for example starch is being metabolized). At 21% O_2, the CO_2 (and O_2) changes we observed were 5.4 ppm (-4.5 ppm), 3.5 ppm (-3.8 ppm), and 3.1 ppm (-3.1 ppm). At 2% O_2, the CO_2 (and O_2) changes were 4.2 ppm (-4.8 ppm), 7.5 ppm (-4.3 ppm), and 7.0 ppm (-6.0 ppm). These experiments show that we are measuring the change in the O_2/N_2 ratio, as air passes through the cuvette, to a precision of order 1 ppm. The single outlier is in the high change in the CO_2 concentration (7.5 ppm) rather than O_2. For the remaining 5 experiments, the change in the O_2 concentration was larger than the change in the CO_2 concentration by 0.2±0.6 ppm. This precision is more than adequate for most calculations in this paper.

Figures:

Fig S1: The variation of C_a (triangles) and C_i (circles) with light intensity for leaves of *Phaseolus vulgaris'* leaves exposed to 21% O_2 (closed symbol) and 2% O_2 (open symbol). Error bars are standard errors for n=3

Fig S2: Correlation between mesophyll conductance calculated using the O_2 method, g_m Renou, and theoretical g_m calculated using the variable J method as in Harley et al (1992), g_m Harley. Dotted line is the 1:1 correlation line.

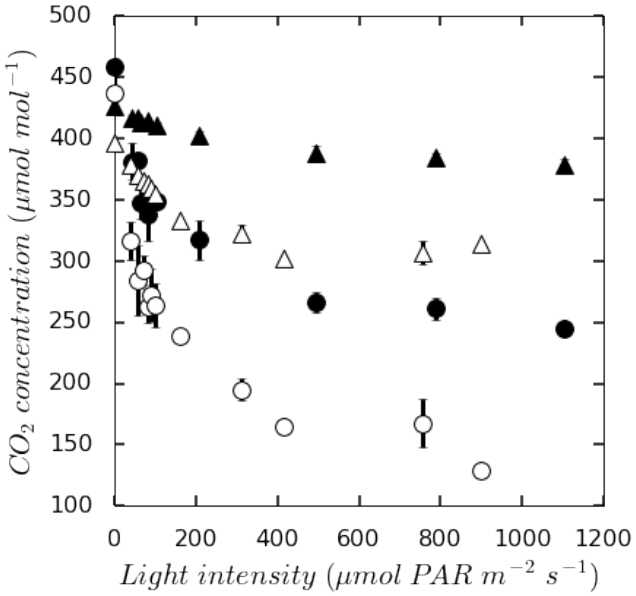
Fig S3: Mesophyll conductance (gm) vs irradiance for *Phaseolus vulgaris'* leaves exposed to 21% O_2. Panel A presents the distribution of mesophyll conductance values around the median (red line). Panel B presents mesophyll conductance values for each of 3 replicates incubations.

Fig S4: $\delta O_2/N_2$ (A), Net O_2 Production (B), $\delta^{18}O$ (C) and Gross O_2 Production (D) for each of 3 replicates incubations vs irradiance for *Phaseolus vulgaris'* leaves exposed to 21% O_2.

Fig S5: $\delta O_2/N_2$ (A), Net O_2 Production (B), $\delta^{18}O$ (C) and Gross O_2 Production (D) for each of 3 replicates incubations vs irradiance for *Phaseolus vulgaris'* leaves exposed to 2% O_2.

Fig S6: Measurements for a *Phaseolus vulgaris*' leaf exposed to 21% O_2. A, B, C: $[CO_2]$, $\delta O_2/N_2$ with respect to dry air reference, and H_2O vapor in air exiting the cuvette. D, E, F: $\delta^{18}O$ of water vapor, $\delta^{18}O$ of O_2, and $\delta^{13}C$ of CO_2 in air exiting the cuvette. G: Photosynthetically Active Radiation (μmol m^{-2} s^{-1}). The shaded areas correspond to times when incoming dry tank air is measured against itself as a reference (for O_2/N_2 and $\delta^{18}O$ of O_2), or to assess baseline stability (pCO_2). The left panel corresponds to the period of labeling of the leaf prior to progressively decreasing irradiance toward zero (right panel). The reference gas is dry tank air entering the cuvette. The clusters of data points beginning at 7.5 hours correspond to measurement periods for different levels of irradiance. $D^{13}C$ of CO_2 was measured but not used in any way in this paper.

Fig S7: Measurement for a *Phaseolus vulgaris*' leaf exposed to 2% O_2. A, B, C: $[CO_2]$, $\delta O_2/N_2$ with respect to dry air reference, and H_2O vapor in air exiting the cuvette. D, E, F: $\delta^{18}O$ of water vapor, $\delta^{18}O$ of O_2, and $\delta^{13}C$ of CO_2 in air exiting the cuvette. G: Photosynthetically Active Radiation (μmol m^{-2} s^{-1}). The shaded areas correspond to times when incoming dry tank air is measured against itself as a reference. The left panel corresponds to the period of labeling of the leaf prior to progressively decreasing irradiance toward zero (right panel). The reference gas is dry tank air entering the cuvette.



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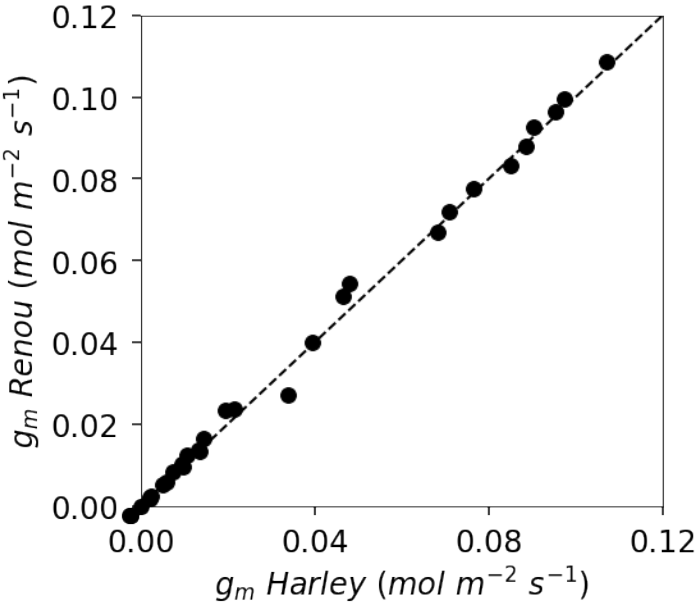

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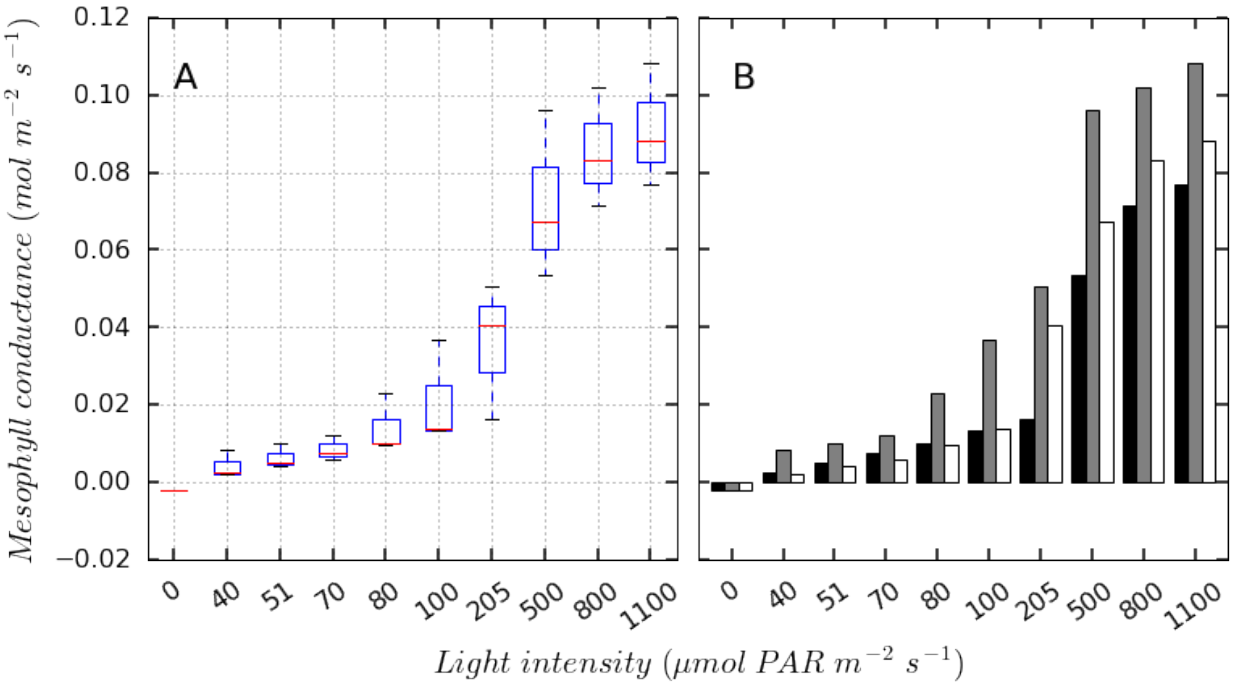

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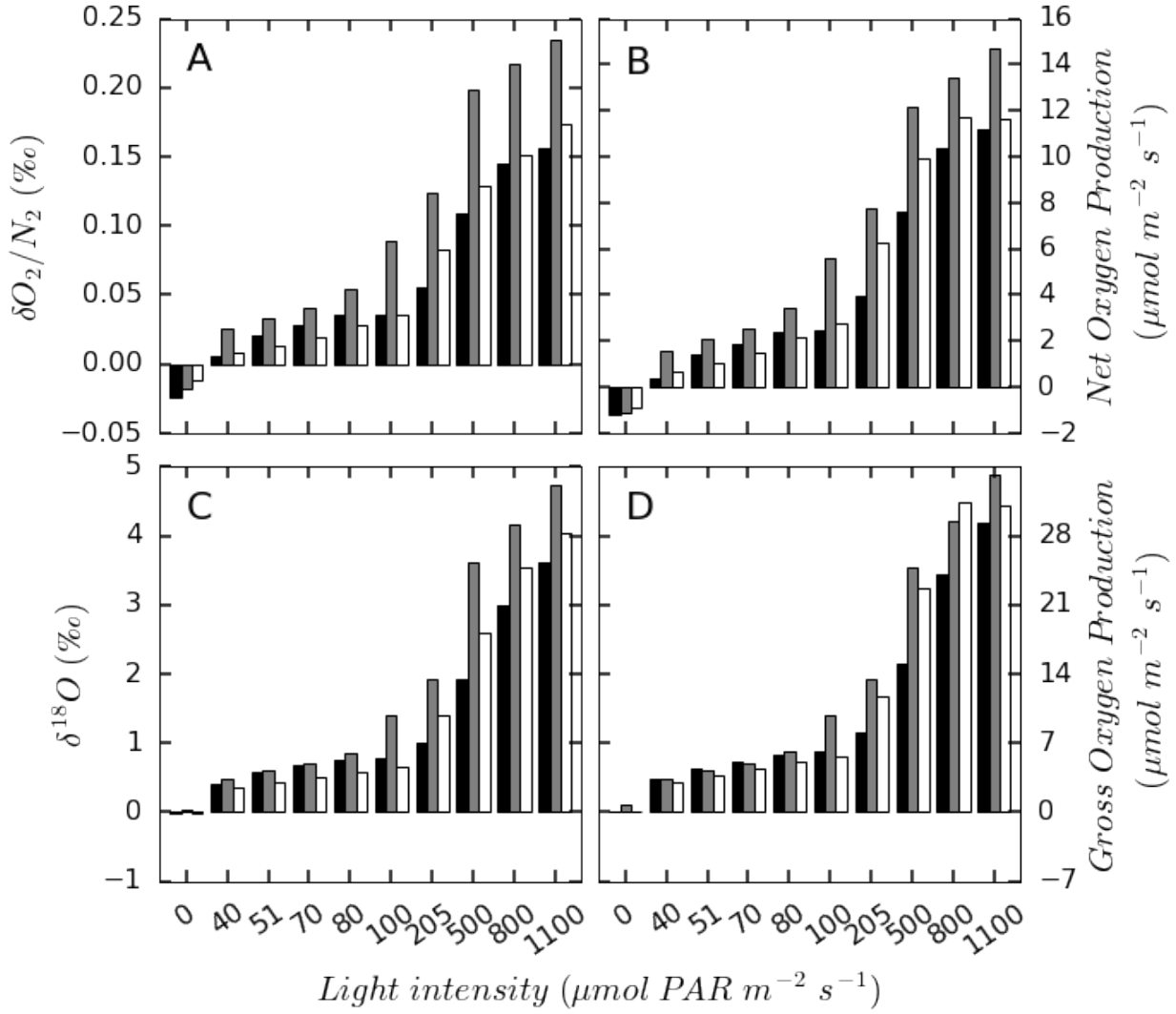

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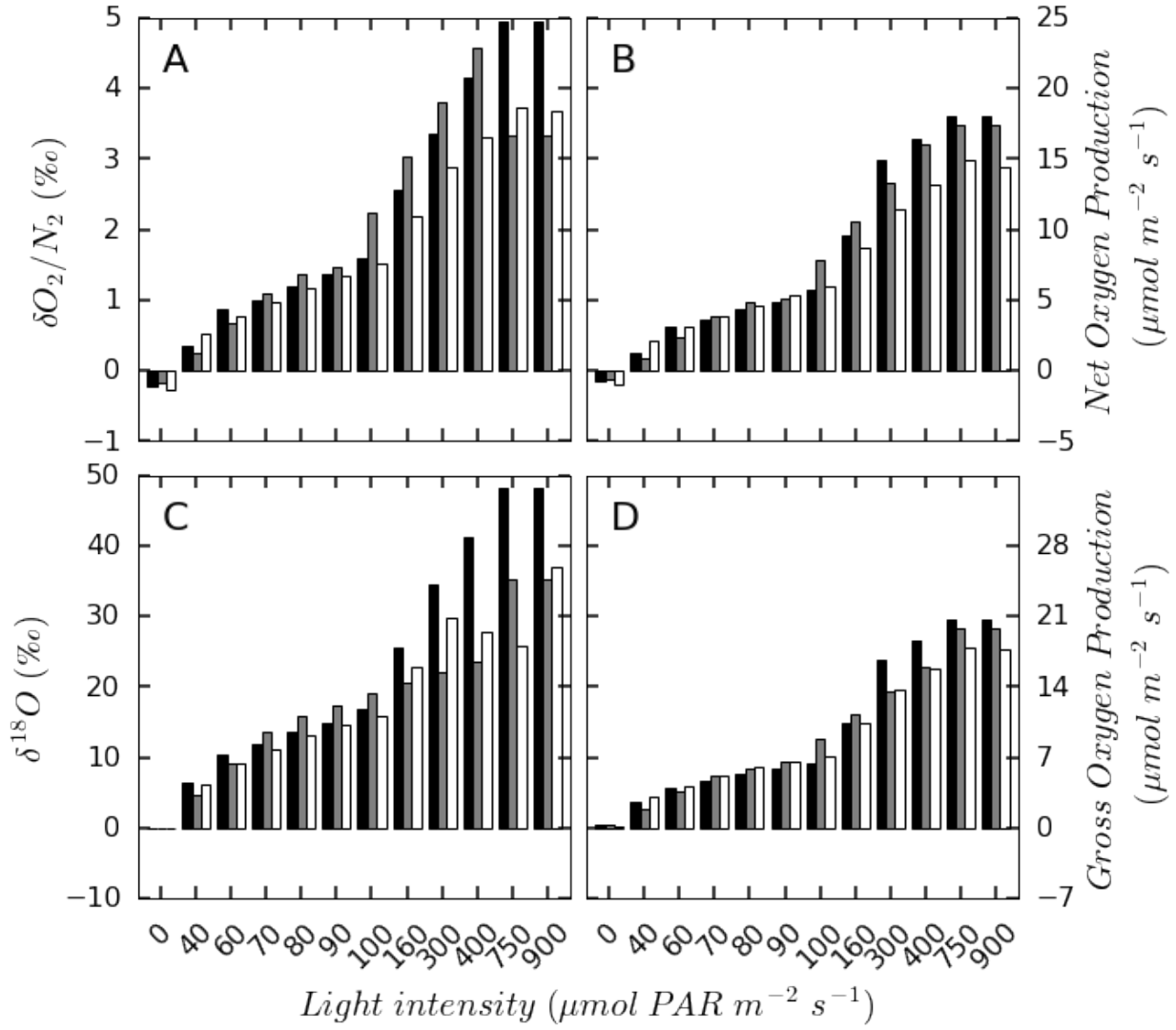

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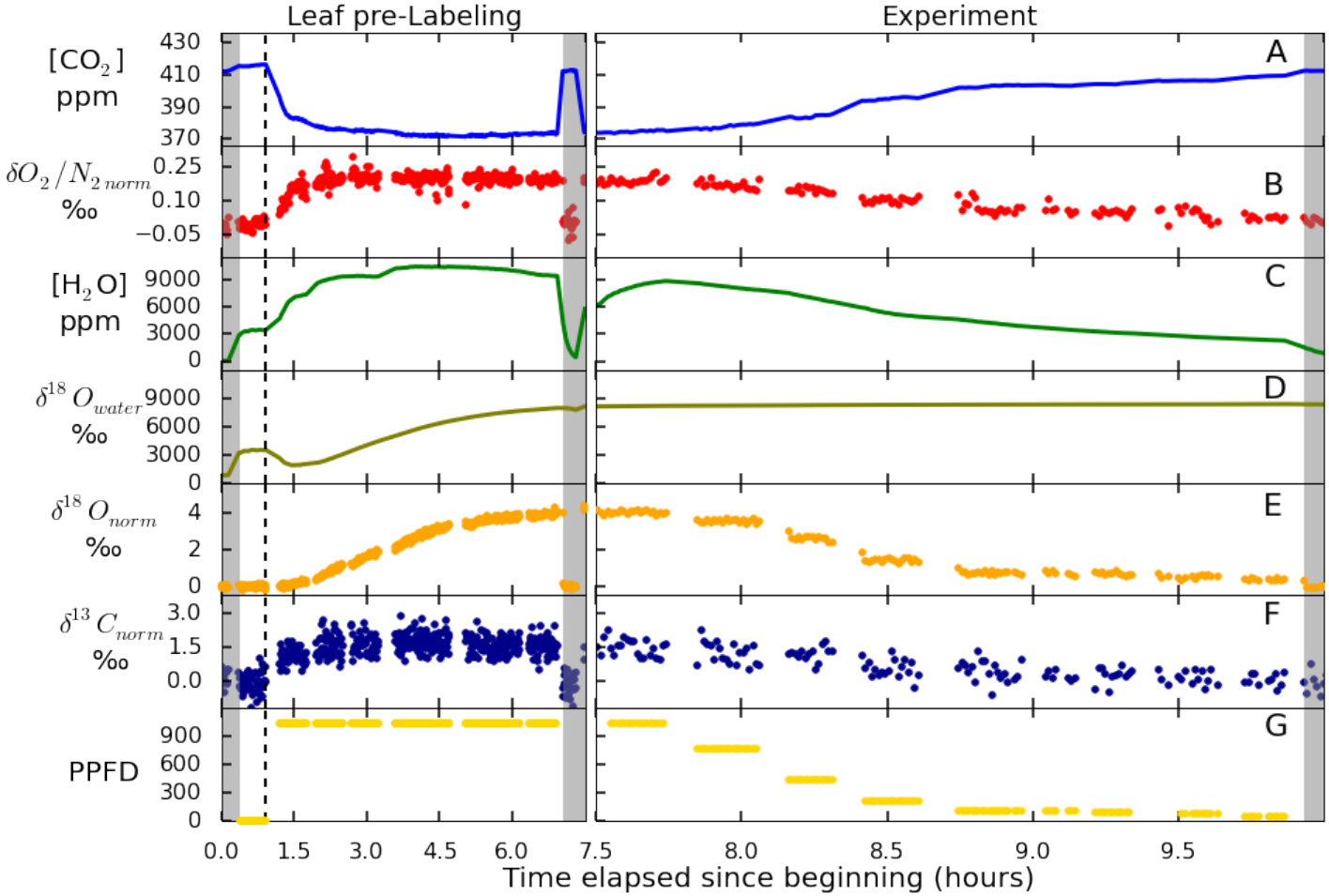

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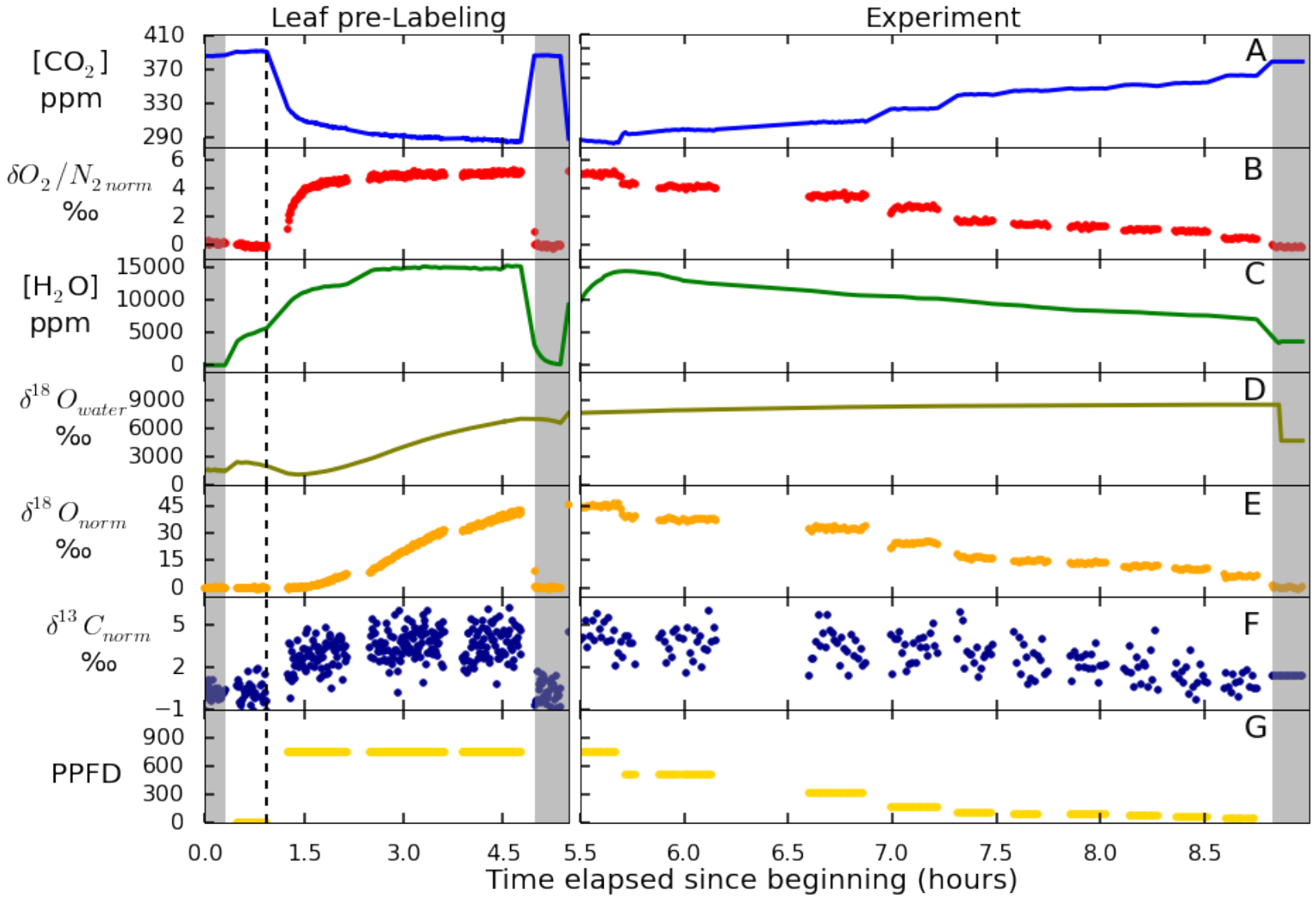

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