Far-red chlorophyll fluorescence radiance tracks photosynthetic carbon assimilation efficiency of dark reactions

Zhunqiao Liu [1], Chenhui Guo [2], Yanwen Bai [2], Nina Zhang [3], Qiang Yu [1,4], Feng Zhao [5] and Xiaoliang Lu [1,*]

[1] State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Institute of Soil and Water Conservation, Northwest A&F University, Yangling 712100, China; zliu@nwafu.edu.cn (Z.L.); yuq@nwafu.edu.cn (Q.Y.)
[2] College of Natural Resources and Environment, Northwest A&F University, Yangling 712100, China; guochenhui@nwafu.edu.cn (C.G.); yanwbai@nwafu.edu.cn (Y.B.)
[3] College of forestry, Northwest A&F University, Yangling 712100, China; zhangnina@nwafu.edu.cn (N.Z.)
[4] Key Laboratory of Water Cycle and Related Land Surface Processes, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China
[5] School of Instrumentation Science and Opto-Electronics Engineering, Beihang University, Beijing 100083, China; zhaofeng@buaa.edu.cn (F.Z.)
* Correspondence: luxiaoliang@nwafu.edu.cn

Contents of this file

Text S1
Figures S1 to S3

Introduction

Figure S1 demonstrates the fluorescence quantum yield of PSII at 760 nm with various CO2 concentrations; Figure S2 displays the fluorescence quantum yield of PSII at 760 nm with various leaf temperatures; Figure S3 shows the fluorescence quantum yield of PSII at 760 nm for pre-treatment and post-treatment of abscisic acid (ABA).

Text S1 Fluorescence quantum yield

Fluorescence quantum yield of PSII at 760 nm (Φ_{ChlF_760}) is defined as the ratio of total emitted chlorophyll fluorescence radiance ($TChlF_{760}$) by photosystem II to absorbed photosynthetically active radiation (APAR):

$$\Phi_{ChlF_760} = \begin{cases} \dfrac{(UChlF_{760} + DChlF_{760})}{\varepsilon_{760} \times f_{APAR} \times PAR \times \beta} \times (1 - 0.24) & C3 \\ \dfrac{(UChlF_{760} + DChlF_{760})}{\varepsilon_{760} \times f_{APAR} \times PAR \times \beta} \times (1 - 0.50) & C4 \end{cases} \qquad \text{Eqn S1}$$

where $UChlF_{760}$ and $DChlF_{760}$ are the upward and downward fluorescence radiance at 760 nm ($\mu W\ cm^{-2}\ nm^{-1}\ sr^{-1}$), respectively. β is the fraction of absorbed PAR that is absorbed by PSII assuming to be 0.5 (Baker 2008). The PSI contribution to fluorescence intensity was assumed to be 0.24 and 0.50 for soybean and maize, respectively (Pfündel et al., 2013). f_{APAR} is the fraction of PAR absorbed by a leaf, and was calculated by leaf reflectance (R) and transmittance (T):

$$f_{APAR} = 1 - (R_\lambda + T_\lambda)\ (400\ nm \le \lambda \le 700\ nm) \qquad \text{Eqn S2}$$

R and T were measured with an integration sphere (ASD Integrating Sphere; ASD Inc, VA, USA) and spectrometer (PSR+ 3500; Spectral Evolution, MA, USA, 350-2500 nm). ε_{760} is the leaf escape fraction of fluorescence photons that escape from all light reaction centers in the leaf, and is approximately equal to the sum of R and T at 760 nm (Liu et al., 2020). The resulting Φ_{ChlF_760} with CO_2 concentrations, leaf temperature, and ABA-treatment can be found in Figures S1, S2, and S3, respectively.

Reference:

Baker, N.R. (2008). Chlorophyll Fluorescence: A Probe of Photosynthesis In Vivo. Annual Review of Plant Biology, 59, 89-113.

Liu, X., Liu, L., Hu, J., Guo, J. and Du, S., 2020. Improving the potential of red SIF for estimating GPP by downscaling from the canopy level to the photosystem level. *Agricultural and Forest Meteorology, 281,* 107846.

Pfündel, E.E., Klughammer, C., Meister, A. and Cerovic, Z.G., 2013. Deriving fluorometer-specific values of relative PSI fluorescence intensity from quenching of F0 fluorescence in leaves of Arabidopsis thaliana and Zea mays. *Photosynthesis Research*, 114(3), 189-206.

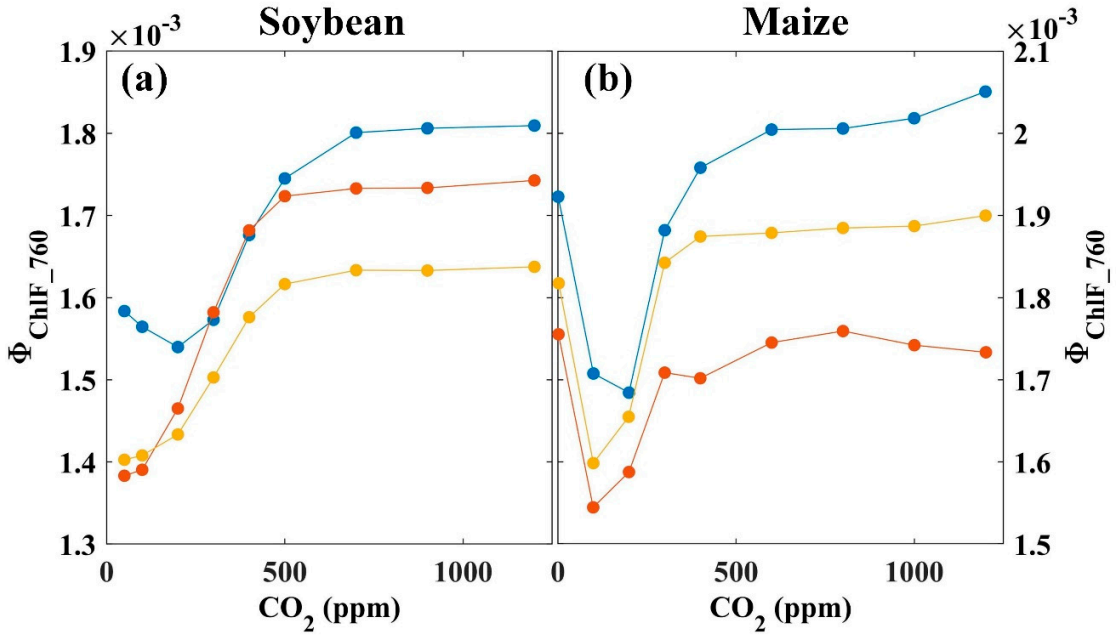


Figure S1. Fluorescence yield at 760 nm (Φ_{ChlF_760}) with CO_2 concentrations (ppm) measured on three leaves of soybean (left column) and maize (right column) under illumination of 800 (soybean) and 1200 (maize) μmol m^{-2} s^{-1}.

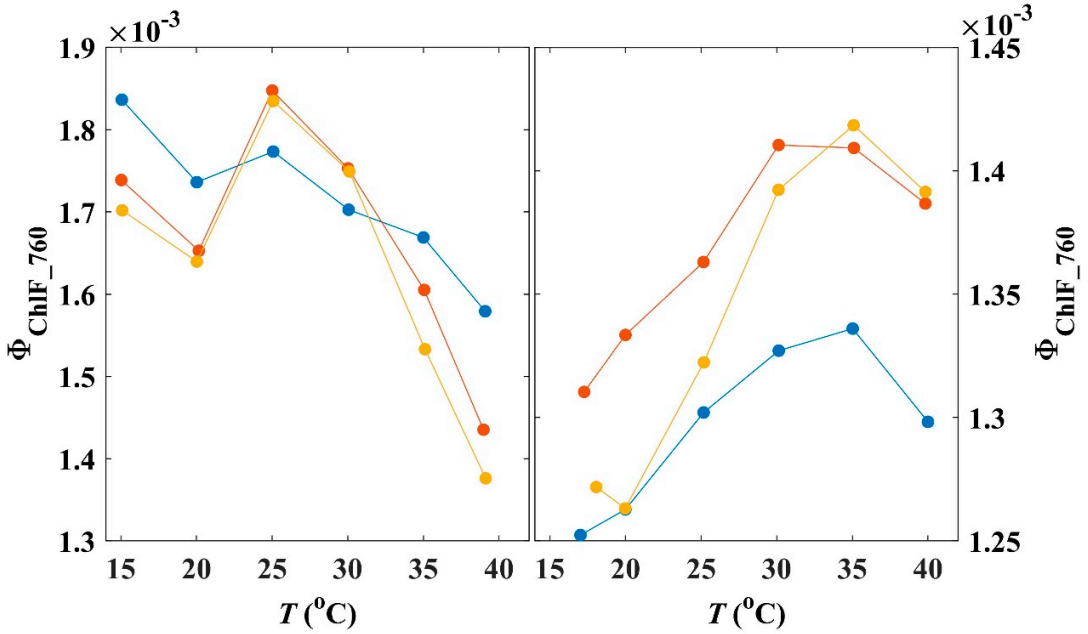


Figure S2. Fluorescence yield at 760 nm (Φ_{ChlF_760}) with leaf temperature (T, °C) measured on three leaves of soybean (left column) and maize (right column) under illumination of 800 (soybean) and 1200 (maize) μmol m^{-2} s^{-1}.

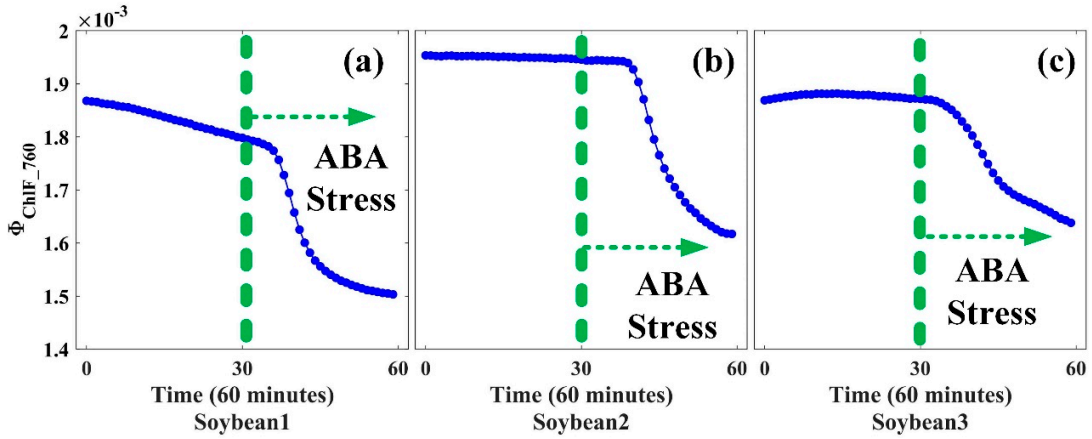


Figure S3. Fluorescence yield at 760 nm (Φ_{ChlF_760}) for pre-treatment and post-treatment of abscisic acid (ABA) under the illumination of 800 μmol m^{-2} s^{-1}. The vertical green dash line indicated the start of ABA treatment.