Open-source LED lamp for the LI-6800 photosynthesis system

Summary

In this work, a cost-effective lamp compatible with the LI-6800 photosynthesis measuring system was developed. The lamp uses a LED, emitting white light with a color temperature similar to sunlight. To demonstrate the functionality of the lamp, measurements of the response of photosynthesis to irradiance were made using BORLAUG100 F2014 wheat line in 2022. In addition, some photosynthetic parameters were estimated form these measurements according to Rivera-Méndez and Romero (2017).

The data described in this text is available on:

https://github.com/AaronVelez/LI-6800_Lamp/tree/main/Data

Data Files

Data files:

- LI-6800_Lamp_AQ_curves.csv
- LI-6800_Lamp_AQ_fittedparams.csv
- LI-6800_Lamp_AQ_curves_InstrumentOutput.csv

Methods and metadata files:

- LI-6800_Lamp_methods_AQcurves.csv
- LI-6800_Lamp_methods_AQparams.csv
- LI-6800_Lamp_instrumentDetails.csv

Data and methods files are in the format according the recommendations of Ely et al. (2021), following the example of Rogers et al. (2019)

Data characteristics

Location	Escuela Nacional de Estudios Superiores Unidad León, León, Guanajuato, México
Latitude	21.04
Longitude	101.67
Altitude	1.787 m ASL
Date from	2022-03-28
Date to	2022-03-28

Data dictionaries

LI-6800_Lamp_AQ_curves.csv
Number of records: 40

Header	Format	Units	Definition
USDA_Species_Code	Alphanumeric string	-	Code to identify the plant species used in measurements according the USDA
Sample_ID	Alphanumeric string	-	Identifier used for each sample
Date	Integer	YYYYMMDD	Date of observations
Time	HH:MM:SS	HH:MM:SS	Time of observations, set to local time (UTC-6)
A	Float	µmol m-2 s-1	CO_2 assimilation rate per leaf area
Ci	Float	µmol mol^{-1}	Intercellular CO_2 concentration
CO2_S	Float	µmol mol^{-1}	CO_2 concentration in air inside chamber
Patm	Float	kPa	Atmospheric pressure
Qin	Float	µmol m-2 s-1	In-chamber photosynthetic flux density (PPFD) incident on the leaf, quanta per area
RHs	Float	%	Relative humidity of air inside the chamber
Tleaf	Float	°C	Leaf surface temperature

LI-6800_Lamp_AQ_fittedparams.csv
Number of records: 4

Header	Format	Units	Definition
USDA_Species_Code	Alphanumeric string	-	Code to identify the plant species used in measurements according the USDA
Sample_ID	Alphanumeric string	-	Identifier used for each sample
Date	Integer	YYYYMMDD	Date of observations
Rd	Float	µmol m-2 s-1	Dark respiration rate derived only from the light response

			curve. Reported as a positive value
Amax	Float	µmol m-2 s-1	Maximum CO_2 assimilation rate
K	Float	µmol m-2 s-1	Light saturation constant
A_model	Float	µmol m-2 s-1	CO_2 assimilation rate modeled using the estimated parameters

LI-6800_Lamp_AQ_curves_InstrumentOutput.csv
Number of records: 40
This file is the output file obtained from the LI-6800 photosynthesis measuring system. The user definitions constants and variables are only described in the following table. The rest of the definitions for the other variables can be obtained from the LI-6800 under **Start Up** > **Data Dictionary.**

Header	Format	Units	Definition
Lamp_Qamb_in_Factor	Float	-	Lamp mismatch factor between Qamb_in and Lamp_PAR_Ctrl
Lamp_T_Ctrl	Float	°C	Lamp temperature setpoint
Lamp_T_trinket_V_Ctrl	Float	V	Lamp input Trinket voltage
Lamp_T_DAC2_V_Ctrl	Float	V	Lamp output Li-6800 voltage from auxiliary channel 2
Lamp_T_TH-r	Float	kohms	Lamp thermistor resistance. Measurement ADC_CH1 to thermistor resistance
Lamp_PAR_Ctrl	Float	µmol m-2 s-1	Lamp desired PAR setpoint
Lamp_T	Float	°C	Lamp temperature. Measurement thermistor temperature to thermistor resistance

Example Data Records:

LI-6800_Lamp_AQ_curves.csv

USDA_Species_Code	Sample_ID	Date	Time	A	Ci	CO2_s	Patm	Qin	RHs	Tleaf
-	-	YYYYMMDD	HH:MM:SS	µmol m-2 s-1	µmol mol-1	µmol mol-1	kPa	µmol m-2 s-1	%	°C
TRITI	P1T	20220328	14:02:54	-0.675960611	131.3564988	400.9432258	82.30613871	-0.264927258	61.71508554	24.80398972
TRITI	P1T	20220328	14:09:33	0.130456267	373.7126274	399.6382258	82.2921129	40.62016129	62.09777041	24.90931618

LI-6800_Lamp_AQ_fittedparams.csv

USDA_Species_Code	Sample_ID	Date	Rd	Amax	K	A_model
-	-	YYYYMMDD	µmol m-2 s-1	µmol m-2 s-1	µmol m-2 s-1	µmol m-2 s-1
TRITI	P1T	20220328	1.590661774	30.7113491	532.8794459	-1.590661774
TRITI	P2T	20220328	2.221156376	30.58111063	438.4365397	-2.221156376

LI-6800_Lamp_AQ_curves_InstrumentOutput.csv

obs time elapsed date hhmmss averaging Lamp_Qamb_in_Factor
Lamp_T_Ctrl Lamp_T_trinket_V_Ctrl Lamp_T_DAC2_V_Ctrl Lamp_T_TH-r
Lamp_PAR_Ctrl Lamp_TTIME E Emm A Ca Ci Pci Pca gsw
gbw gtw gtc Rabs TleafEB TleafCnd SVPleaf RHcham VPcham
SVPcham VPDleaf LatHFlux SenHFlux NetTherm EBSum Asty Esty
Adyn Crd Csd dCsd/dt αVc Edyn Hr Hs dHs/dt αVh
Leak LeakPct CorrFact CorrFactPct Fan Qin Qabs alpha convert S
K Geometry Custom UseDynamic TIME CO2_s CO2_r H2O_s H2O_r
CO2_a H2O_a Flow Pa ΔPcham Tair Tleaf Tleaf2 Offset Offset2
Fan_speed Qamb_in Qamb_out ΔCO2 CO2_s_d CO2_r_d
ΔH2O CO2_b H2O_b e_s e_r Td_s Td_r time hhmmss co2_t
h2o_t count co2_adj h2o_adj co2_match h2o_match co2_at h2o_at
co2_cv h2o_cv CO2_r:MN CO2_r:SLP CO2_r:SD CO2_r:OK CO2_s:MN
CO2_s:SLP CO2_s:SD CO2_s:OK gsw:MN gsw:SLP gsw:SD
gsw:OK Stable Total State Vflow VPchamber abs_c_a abs_c_b
abs_h_a abs_h_b Wc_s Wc_r Wco_s Wco_r Ww_s Ww_r Wwo_s
Wwo_r Flow_s_v Flow_r_v Tleaf_mv Tleaf2_mv Tleaf_j Tleaf2_j
Console_RH Console_T Console_H2O Fan_% Flow_% Pump Tchp_pwm
Txchg_pwm diag_20v diag_5_4v diag_12v diag_5va diag_3_3vf
AccH2O_des CO2_hrs AccCO2_soda AccH2O_hum ADC_CH1 ADC_CH2
ADC_CH3 ADC_CH4 ADC_CH5 ADC_CH6 ADC_CH7 ADC_CH8
DAC_1 DAC_2 DAC_3 DAC_4 GPIO GPIO_dir excit_5v power_12v
power_5v ch1_pullup AuxPower MatchValveR MatchValveS MatchCO2
MatchH2O cf_co2_a cf_co2_b cf_co2_c cf_co2_d cf_h2o_a
cf_h2o_b cf_h2o_c cf_h2o_d co2_fit_low co2_fit_high h2o_fit_low
h2o_fit_high co2_elapsed h2o_elapsed CO2_f CO2_f_s Pump_f Pump_f_s
Pump_p Pump_p_s Tboard V_system DIAG Flow_s Flow_r Txchg
Tirga Tchopper Ts Tr CO2_% Desiccant_% Humidifier_% Txchg_sp
CO2_r_sp H2O_r_sp SS_s SS_r

	s	s			s		°C	V	V	kohms	
	µmol m-2 s-1		°C	s	mol m^{-2} s^{-1}		mmol m^{-2} s^{-1}		µmol m^{-2} s^{-1}		
	µmol mol^{-1}		µmol mol^{-1}		Pa	Pa	mol m^{-2} s^{-1}		mol m^{-2} s^{-1}		mol
m^{-2} s^{-1}	mol m^{-2} s^{-1}		W m^{-2}	°C	°C	kPa	%	kPa	kPa	kPa	W
m^{-2}	W m^{-2}	W m^{-2}	W m^{-2}	µmol m^{-2} s^{-1}		mmol m^{-2} s^{-1}		µmol m^{-2} s^{-1}		µmol mol^{-1}	
	µmol mol^{-1}		µmol mol^{-1} s^{-1}		cm^{3}	mmol m^{-2} s^{-1}		mmol mol^{-1}		mmol mol^{-1}	
	mmol mol^{-1} s^{-1}		cm^{3}	µmol s^{-1}		%		%	µmol s^{-1}		
	µmol m^{-2} s^{-1}		µmol m^{-2} s^{-1}			J/µmol	cm^{2}			mol m^{-2} s^{-1}	
		s	µmol mol^{-1}		µmol mol^{-1}		mmol mol^{-1}		mmol mol^{-1}		
	µmol mol^{-1}		mmol mol^{-1}		µmol s^{-1}		kPa	kPa	°C	°C	°C
	°C	°C	rpm	µmol m^{-2} s^{-1}		µmol m^{-2} s^{-1}		µmol mol^{-1}		µmol mol^{-1}	
	µmol mol^{-1}		mmol mol^{-1}		µmol mol^{-1}		mmol mol^{-1}		kPa	kPa	°C
	°C	secs		s	s		µmol/mol		mmol/mol		
	µmol/mol		mmol/mol		µmol/mol		mmol/mol		%	%	
	µmol mol^{-1}		µmol mol^{-1} min^{-1}			µmol mol^{-1}			µmol mol^{-1}		
	µmol mol^{-1} min^{-1}			µmol mol^{-1}			mol m^{-2} s^{-1}		mol m^{-2} s^{-1} min^{-1}		
	mol m^{-2} s^{-1}						V	V			
										V	V
	mV	mV	°C	°C	%	°C	mmol mol^{-1}		%	%	
	V	V	V	V	V	V	V	mg	hrs	mg	mg
	V	V	V	V	V	V	V	V	V	V	V
	V							V	%	%	
	µmol/mol		mmol/mol		mmol/mol					mmol/mol	
				µmol mol^{-1}		µmol mol^{-1}		mmol mol^{-1}		mmol mol^{-1}	
	min	min	V	V	V	V	V	V	°C	V	
	µmol s^{-1}		µmol s^{-1}		°C	°C	°C	°C	°C	%	%
	%	°C	µmol mol^{-1}		mmol mol^{-1}		%	%			

1 1648497774 0 20220328 14:02:54 14:02:54 5 1 30
1.2375 1.165834725 9.508138538 0 26.1535609 1648497766 -
6.20657E-05 -0.062065666 -0.675960611 400.9432258 131.3564988
10.81801895 33.02015093 -0.004106839 2.647558449 -0.004110382 -
0.00256867 -0.050627599 24.80398972 24.80398972 3.142709203
61.71508554 1.937507947 3.139439781 1.205201257 2.737095878 -
2.488109929 -0.198375767 -1.74178E-05 -0.843962533 -0.059210232 -
0.675960611 409.7121036 410.4587515 0.000784953 88.54033749 -
0.062065666 23.58963787 23.52348022 4.61859E-06 104.7179606 0 0
1 0 39560.94932 -0.264927258 -0.211941806 0.8 0.1911 3
0.5 0: Broadleaf 2 VERDADERO 1648497766 400.9432258
399.996871 23.52595806 23.58901613 400.3902258 23.41995806
275.0667419 82.30613871 0.050037445 24.78655806 24.99152903
999.9 0 0 8996.270323 -0.264927258 0.235416226
0.836778194 410.4877419 409.6602903 -0.070627823 399.996871
23.58901613 1.935707419 1.94152129 16.92800968 16.97530968
1648497797 14:03:16 1648497796 1648497797 2 0.11
0.006 0.553 0.106 400 24 0.58 0.19 399.9992459 0.01394183
0.059319268 1 400.840377 -0.088093072 0.031642555 1 -
0.004345783 0.000294946 0.000156434 1 3 3 3/3 2.26348
2.68022 0.0755662 0.0753011 0.0922028 0.0908475
26850.3 24308 28446.1 25180.8 34888.4 31432.5
41738.4 37165.1 1.4953 1.49248 -0.013005 0
25.2067 25.9035 51.111 31.28 28.4622 53.79 25.9415
0.5 0.629774 1.5905 20.3086 5.25712 11.9433
4.99315 3.299 9999 678.1 6362.6 9999 2.44594 2.92305
1.87393 1.87851 1.8768 1.87806 1.87233 1.87881
0 0.3762 0 0 11111100 oooooooo off off on
off 0 100 100 0.553 0.106 0.157714809 0.000723023 -
1.21059E-08 -2.82691E-11 -0.063168674 -0.013223211 0.001240205 -1.62673E-
05 2 2096 1 33 9.5 9.5 0.778809 2.52808
0.947266 2.10815 0.994873 2.28149 34.7837
24.0262 18 260.55 263.587 24.4192 34.6925
29.9998 35.2818 35.3058 15.5409 30.7562
32.3048 24.4189 400 23.5823 98.1011 97.1331

Data Acquisition Materials and Methods

Instrument: LI-6800 photosynthesis measuring system.

The complete methods for the the light response curve is available in:
https://github.com/AaronVelez/LI-6800_Lamp/blob/main/Software/A-PPFD_Curve.py

References

Ely, K. S., Rogers, A., Agarwal, D. A., Ainsworth, E. A., Albert, L. P., Ali, A., … Yang, D. (2021). A reporting format for leaf-level gas exchange data and metadata. Ecological Informatics, 61, 101232. https://doi.org/10.1016/j.ecoinf.2021.101232

Rogers, A., Serbin, S. P., Ely, K. S., & Wullschleger, S. D. (2019). Terrestrial biosphere models may overestimate Arctic CO2 assimilation if they do not account for decreased quantum yield and convexity at low temperature. New Phytologist, 223(1), 167–179. https://doi.org/10.1111/nph.15750

Rivera-Méndez, Y. D., & Romero, H. M. (2017). Fitting of photosynthetic response curves to photosynthetically active radiation in oil palm. Agronomía Colombiana, 35(3),323-329.