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 PINTO SALTILLO bean line in 2024. In addition, some photosynthetic parameters were estimated form these measurements according to Busch et al. (2024).

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_Bean_AQ_curves.csv
LI-6800_Lamp_ Bean_AQ_fittedparams.csv
LI-6800_Lamp_ Bean_AQ_curves_InstrumentOutput.csv

Methods and metadata files:

LI-6800_Lamp_ Bean_methods_AQcurves.csv
LI-6800_Lamp_ Bean_methods_AQparams.csv
LI-6800_Lamp_ Bean_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	2024-03-21
Date to	2024-03-22

Data dictionaries

LI-6800_Lamp_ Bean_AQ_curves.csv
Number of records: 50

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_ Bean_AQ_fittedparams.csv
Number of records: 5

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
Phi_CO2	Float	-	Quantum efficiency of CO_2 assimilation
A_Sat	Float	µmol m-2 s-1	Light saturated CO_2 assimilation rate

Rd	Float	µmol m-2 s-1	Dark respiration rate derived only from the light response curve
Theta	Float	-	Empirical curvature factor of the response of CO_2 assimilation to the light
I_comp	Float	µmol m-2 s-1	Light compensation point

LI-6800_Lamp_ Bean_AQ_curves_InstrumentOutput.csv

Number of records: 50

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_PAR_Ctrl	Float	µmol m-2 s-1	Lamp desired PAR setpoint
Lamp_T_Ctrl	Float	°C	Lamp temperature setpoint
Lamp_Qamb_in_Factor	Float	-	Lamp mismatch factor between Qamb_in and Lamp_PAR_Ctrl
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_T	Float	°C	Lamp temperature. Measurement thermistor temperature to thermistor resistance
Lamp_PAR_DAC1_Ctrl	Float	V	Lamp output Li-6800 voltage to obtain the desired PAR setpoint

Example Data Records:

LI-6800_Lamp_ Bean_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
PHVU	Bean1	20240322	14:36:54	-1.613576991	400.2670327	400.09	82.0933	-0.154137	56.98042611	25.0162
PHVU	Bean1	20240322	14:48:09	0.948748533	376.0389014	400.03	82.0997	40.0629	59.65035529	25.0068

LI-6800_Lamp_ Bean_AQ_fittedparams.csv

USDA_Species_Code	Sample_ID	Date	Phi_CO2	A_sat	Rd	Theta	I_comp
-	-	YYYYMMDD	-	µmol m-2 s-1	µmol m-2 s-1	-	µmol m-2 s-1
PHVU	Bean1	20240322	0.060596005	19.36587742	1.536771248	0.78112109	25.80142873
PHVU	Bean2	20240321	0.053367097	20.55056813	1.426724917	0.867451499	26.98018061

LI-6800_Lamp_ Bean_AQ_curves_InstrumentOutput.csv

USDA_Species_Code	Sample_ID	obs	time	elapsed	date	hhmmss	averaging		
Lamp_PAR_Ctrl	Lamp_T_Ctrl	Lamp_Q	amb_in_Factor	Lamp_T_trinket_V_Ctrl					
Lamp_T_DAC2_V_Ctrl	Lamp_T_TH-r	Lamp_T	Lamp_PAR_DAC1_Ctrl	TIME	E				
Emm	A	Ca	Ci	Pci	Pca	gsw	gbw	gtw	gtc	Rabs
TleafEB	TleafCnd	SVPleaf	RHcham	VPcham	SVPcham	VPDleaf				
LatHFlux	SenHFlux	NetTherm	EBSum	Leak	LeakPct	CorrFact				
CorrFactPct	Fan	Qin	Qabs	alpha	convertS	K	Geometry			
Custom	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	H2O_s:MN					
H2O_s:SLP	H2O_s:SD	H2O_s: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	AccCO2_soda	CO2_hrs						
AccH2O_des	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	umol m^-2 s^-1			°C
		V	V	kohms	°C	V	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 s?¹		%		%	
	µmol s?¹		µmol m?² s?¹		µmol m?² s?¹			J/µmol	cm²		
	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			mmol mol?¹	mmol mol?¹ min?¹			
	mmol mol?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		µmol/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		%	%			

PHVU	Bean1	1	1711139814	0	20240322 14:36:54	14:36:54			
	none	0	30	1.053759919	1.2375	0	11.39255724	0	
	1.29E-15		1711139814	0.003958952	3.958951528	-1.613576991			
	400.09	400.2670327	32.87922316	32.86468113	0.278661499				
	2.506067093	0.262520691	0.165447657	-0.030056715	24.53932705				
	24.53932705	3.093388986	56.98042611	1.892218372	3.32082173				
	1.201170613	-174.5897624	160.9359103	13.60228033	-0.081628501	10			
	4	1	0	39382.31518	-0.154137	-0.02466192	0.16		
	0.195	9	0.5	0: Broadleaf	2	1711139814	400.09	399.993	
	23.0356		10.378	396.633	22.9076	275.011	82.0933		
	0.0499206		25.7305	25.0162	998.15	0	-1.75	9007.5	-
0.154137	3.98461		-0.0492554	409.362	404.187	12.6311			
	399.993		10.378	1.8889	0.851965	16.5425	4.60393		
	1711139855		14:37:35	1711139828	1711135652	69	0.147	0.01	
	3.457	0.128	400	24	0.46	0.02	400.0048167	0.057174215	
	0.109385174		1	399.9815	-0.020112253	0.044482394	1		
	23.082865		-0.09109347	0.027122874	1	3	3	03-mar	
	2.26976		2.68029	0.0756846	0.0758764	0.0914765			
	0.0501409		26883.7	24573	28473.2	25458.3	34919.7		
	33142.8		41749.9	37501.8	1.4789	1.54368	0.042282		
	0	24.3221		999.9	52.79	28.52	25.1515	47.8897	
	26.3341		0.5	0.259284	-0.610289	20.3199	5.25862		
	11.9403		4.9953	3.299	9999	999.9	9999	9999	2.55533
	1.87424		1.87332	1.87787	1.87621	1.87756			
	1.87173		1.87821	0	1.1658	0	0	11111010	
	oooooooo		off	off	on	off	0	100	100	3.457
	0.128	3.026929278	0.000723023	-1.21E-08	-2.83E-11	-			
0.050759539	-0.013223211		0.001240205	-1.63E-05	2	2096	1	33	
	86.5	69.4	0.76416	2.55859	0.947266	2.11182			
	0.996094		2.2937	31.9365	24.035	18	239.854	267.864	
	26.6588		30.375	30	30.8131	30.837	15.2525	65.8587	
	0	26.6571		400.018	10.4006	98.1552	98.0901		

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

Busch, F. A., Ainsworth, E. A., Amtmann, A., Cavanagh, A. P., Driever, S. M., Ferguson, J. N., … Papanatsiou, M. (2024). A guide to photosynthetic gas exchange measurements: Fundamental principles, best practice and potential pitfalls. Plant Cell and Environment, 1–21. https://doi.org/10.1111/pce.14815