Spectral Errors from Four Commercial Quantum Sensors Under LEDs and Other Electric Lights

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Introduction

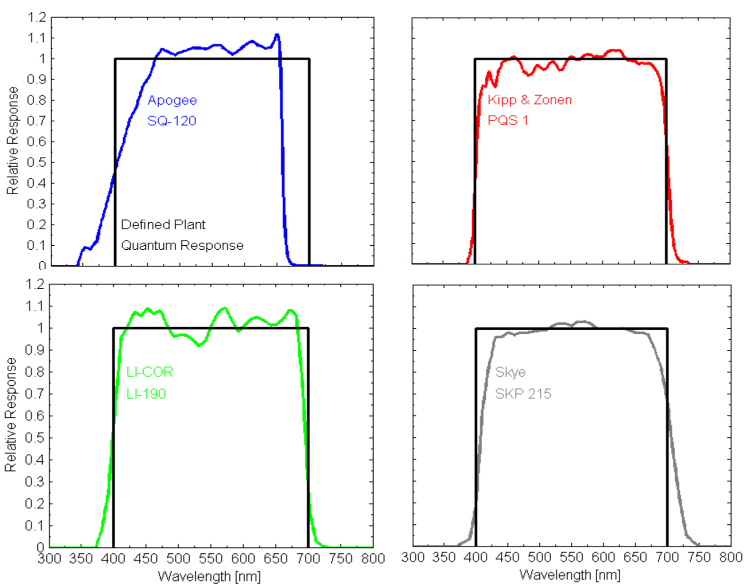
- Light emitting diode (LED) technology has advanced rapidly in recent years and LEDs are increasingly being used in plant growth chambers.
- Measurement of photosynthetic photon flux (PPF, μmol m^{-2} s^{-1}) using quantum sensors can be associated with significant errors for two reasons:
  - **Unique spectral output of LEDs** (for example, narrowband output).
  - **Non-ideal spectral response of quantum sensors** (no commercially available quantum sensors match the defined quantum response of equal weighting of all photons between 400 and 700 nm).
- Despite challenges, quantum sensors are often used to measure PPF under LEDs because they are simple and cost effective relative to spectroradiometers.

Measurements and Calculations

- Spectral errors for four commercially available quantum sensors were determined for eight different LEDs and six common electric lights used in growth chambers:

Quantum Sensors	LEDs	Electric Lights
Apogee model SQ-120	Cool White Fluorescent (CWF)	T5 Cool White Fluorescent
Kipp & Zonen model PQS 1	Neutral White Fluorescent (NWF)	T8 Cool White Fluorescent
LI-COR model LI-190	Warm White Fluorescent (WWF)	T12 Cool White Fluorescent
Skye model SKG 215	Blue (448 nm peak ± 10 nm)	Compact Fluorescent (CF)
	Green (524 nm peak ± 15 nm)	Metal Halide (MH)
	Red (635 nm peak ± 10 nm)	High Pressure Sodium (HPS)
	Red, Blue Mixture (85 % R, 15 % B)	
	Red, Green, Blue Mixture (72 % R, 16 % G, 12 % B)	

- Spectral responses of quantum sensors, shown below, were **determined with a monochromator** (except for the Skye SKG 215, which came from the manufacturer).
- Method of Federer and Tanner (1966) was used to **calculate quantum sensor spectral errors for PPF measurement** based on radiation source spectral outputs and sensor spectral responses.
- Method only calculates spectral error and does not consider **cosine** and **calibration** errors.



Measured spectral responses of quantum sensors (except Skye sensor, which came from manufacturer's specifications). The closer the spectral response matches the defined plant quantum response, the smaller spectral errors will be. NOTE: Lights that output a large proportion of radiation between 660 and 700 nm should not be measured with an Apogee quantum sensor.

Relative Spectral Comparisons

PPF Spectral Errors Under Electric Lights (Errors are Relative to T5 Cool White Fluorescent)

Radiation Source	Apogee SQ-120	Kipp & Zonen PQS 1	LI-COR LI-190	Skye SKP 215
T5 CWF	0.0	0.0	0.0	0.0
T8 CWF	-0.3	0.0	0.5	-0.3
T12 CWF	-1.2	-0.6	0.9	-1.1
CF	-0.2	1.0	1.0	0.6
MH	-3.9	-1.7	0.2	-2.4
HPS	0.8	1.4	1.4	0.5
LEDs				
CWF	-4.2	-0.6	1.2	-0.1
NWF	-6.1	0.0	0.9	0.3
WWF	-9.9	0.4	0.7	0.5
Blue (448 nm)	-10.7	-1.7	5.9	-3.1
Green (524 nm)	5.8	-2.4	-4.5	1.2
Red (635 nm)	4.7	2.0	2.1	-0.3
Red, Blue	2.7	1.7	2.8	-0.6
Red, Green, Blue	3.5	0.5	1.3	-0.4

Conclusions

- Spectral errors were typically smaller for common electric lights relative to LEDs, where spectral errors for all quantum sensors were less than 4 % for common electric lights and less than 11 % for LEDs.
- Spectral errors were typically smaller for mixed and broadband (white) LEDs relative to single color LEDs, where spectral errors for all quantum sensors were less than 4 % for mixed LEDs.
- Quantum sensors can be a very practical means of measuring PPF from LEDs, but spectral errors must be considered. Errors presented in the table above can be used as correction factors for different electric light sources.

References

Federer, C.A. and C.B. Tanner, 1966. Sensors for measuring light available for photosynthesis. Ecology 47:654-657.