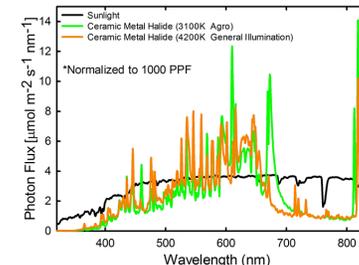
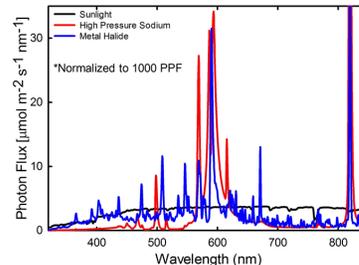
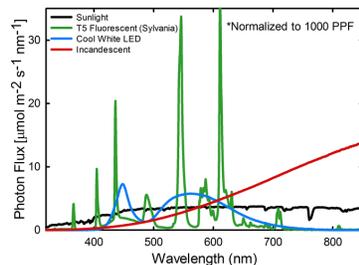
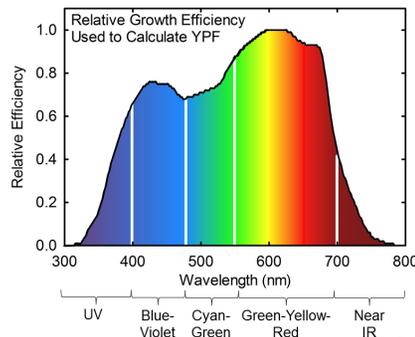


Spectral characteristics of lamp types for plant biology

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		Radiation distribution (% of PPF)							Ratios important to Photosynthesis		Ratios important to Phytochrome		
		%UVB (287-320)	%UVA (320-399)	Weighted UV ¹	Totals to 100%			YPF PPF	PPE klux	Skye ³ (630-660) PPE ² Red/FR (712-742) ⁴			
					%Violet-Blue (400-475)	%Cyan-Green (476-550)	%Green-Yellow-Red (551-700)	%Near IR (701-850)					
Sunlight-Solar Noon													
18-Mar	Clear	0.39	8.3	3.9	20.4	25.5	54.3	50.4	0.899	16.2	0.72	1.06	1.07
26-May	Clear	0.47	8.5	4.3	20.2	25.3	54.7	50.8	0.901	16.2	0.72	1.03	1.08
11-May	Cloudy	0.51	8.8	4.5	20.2	25.3	54.7	53.7	0.902	16.2	0.71	0.98	1.02
High Intensity Discharge													
HPS	Philips	0.01	0.8	0.3	4.4	6.0	89.7	56.6	0.95	10.9	0.87	3.3	3.65
Metal Halide	GE	0.13	8.2	2.9	18.9	22.7	58.4	26.5	0.91	13.4	0.80	2.5	2.38
MH Conversion	EYE	0.03	5.0	1.6	16.3	29.1	54.7	22.7	0.89	11.6	0.82	4.2	3.66
1:1 HPS MH Mix⁵		0.06	1.7	0.5	10.6	14.8	74.6	21.1	0.92	11.8	0.83	3.3	3.03
Ceramic Metal Halide													
4200 K	Philips	0.03	1.9	0.5	13.2	25.7	61.2	18.1	0.892*	14.3	0.82	4.1	3.68
3100 K	Philips (Agro)	0.01	0.4	0.1	11.7	19.4	69.1	21.7	0.898	15.8	0.82	2.7	2.72
VHO Fluorescent													
T12	Sylvania	0.55	2.7	3.0	18.5	20.0	61.5	3.4	0.89	12.0	0.83	8.6	7.09
T12	GE	0.43	2.8	2.2	17.7	21.4	60.9	4.0	0.89	11.9	0.83	10.3	6.42
T12	Philips	0.49	2.1	2.7	16.2	21.5	62.3	4.4	0.89	11.7	0.83	6.9	7.33
HO Fluorescent													
T8	Sylvania	0.32	1.7	1.7	14.2	29.2	56.6	3.2	0.89	11.8	0.84	5.8	6.19
T8	GE	0.30	1.6	1.6	11.6	29.5	58.9	4.7	0.91	11.8	0.84	4.0	4.52
T8	Philips	0.40	1.5	1.9	8.3	30.6	61.1	5.1	0.92	11.9	0.85	4.0	4.29
T5	Sylvania	0.10	2.1	1.3	18.1	34.1	47.8	3.6	0.89	12.2	0.83	3.9	4.50
T5	GE	0.11	1.8	1.2	17.2	34.7	48.1	3.4	0.89	12.1	0.83	3.9	4.62
T5	Philips	0.11	1.9	1.3	20.1	31.9	48.0	3.8	0.89	12.7	0.82	3.9	4.37
LEDs													
Warm		0.00	0.0	0.0	8.2	16.4	75.5	7.3	0.91	14.2	0.84	4.7	5.01
Neutral		0.00	0.0	0.0	14.8	22.7	62.6	4.8	0.88	13.1	0.84	5.5	5.40
Cool		0.00	0.1	0.0	22.1	25.4	52.5	2.8	0.86	12.7	0.83	5.9	6.14
Red/Blue Mix		0.00	0.0	0.0	14.5	0.7	84.8	0.7	0.94	29.3	0.88	86/0	193
Compact Fluorescent													
Cool White	Sylvania	0.10	1.9	1.4	12.7	29.1	58.2	5.5	0.92	12.4	0.84	3.4	4.11
UV	Black Light	13	756	326	92.0	3.2	4.8	23.6	3.01	105	0.75	0.0	0.08
Incandescent		0.02	0.7	0.6	4.8	14.4	81.2	167.5	0.97	19.0	0.65	0.6	0.65
Quartz Halogen⁶		0.14	1.9	2.5	7.3	17.2	75.8	128.7	0.95	17.8	0.67	0.7	0.73

Compared to sunlight, all lamps are low in UV radiation. Measurement of the weighted UV is recommend to quantify the UV effects, but this measurement must be made with a UV calibrated spectro-radiometer capable of accurate measurements to 280 nm.

Blue light is low in HPS lamps. Mixing of HPS and MH lamps, or using Ceramic Metal Halide lamps is necessary to provide adequate blue light with high intensity and efficiency.

The ratio of YPF to PPF ranges from 0.89 to 0.91 for most light sources. Higher values for this ratio (0.95; HPS lamps) indicate that plant growth might be slightly better than the PPF as measured by a standard quantum sensor.

* The spectrum of the Phillips Agro Ceramic Metal Halide lamp (3100K) is shifted toward the red wavelengths. This change increases the YPF/PPF ratio from 0.892 to 0.898.

The PPF/kilolux ratio can be used to interconvert between visible light and PPF. This conversion is based on the new luminous efficiency functions (CIE 2006)

The red/far-red ratio varies widely because there are only trace amounts of far-red radiation from many lamps. The measurement of Phytochrome Photoequilibria (PPE) may provide a more comprehensive measurement of the effects of phytochrome on plant development, but PPE still underestimates the effects of blue light. According to the PPE, the radiation from all common lamps would be perceived as bright sunlight, since the PPE is greater than 0.72.

Footnotes

- Biologically weighted UV using weighting factors from Flint and Caldwell (2003). Normalized to a PPF of 1000.
- Phytochrome Photo-Equilibrium, also called PPS (Phytochrome Photo-Stationary State).
- Measured with a Skye Instruments Red/Far Red Sensor, which has two bell-shaped curves with 655 and 735 peaks. Each curve is ±20 nm.
- Calculated from spectrometer to approximately match Skye Sensor; square wave with equal weighting of photons.
- Filtered through a glass barrier
- LICOR model 1800-02 Calibration Lamp.

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