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Lighting Metrics … And What Matters

With the continuing development of light-emitting diodes (LEDs) and other lighting technologies, there are various metrics that academics and lighting companies use to communicate information on lamps for plant applications. Some of the metrics are marketed for competitive purposes while others are more descriptive.

This article discusses some of the metrics used to describe or quantify the light emitted from various fixtures (or LED arrays), some of which are highly relevant to plant applications and others that are only applicable to people.

Photosynthetically active radiation (PAR) refers to the waveband of light between 400 and 700 nanometers (nm). This waveband correlates very well with the energy of photons that can stimulate photosynthesis in plants, and outside of this range, photons are less or not effective. Thus, this is the waveband used when the amount, or intensity, of photosynthetic light is measured or reported.

Photosynthetic photon flux (PPF) is the amount of PAR (number of photons between 400 and 700 nm) emitted from a lamp per second. The unit is micromoles (µmol) per second (s), abbreviated $\mu mol \cdot s^{-1}$ or µmol/s. This value is usually measured in a lab with a very expensive integrating sphere, which captures essentially all photons emitted from a lamp.

Photosynthetic photon flux density (PPFD) is the PPF incident upon a square meter (m^2) with units of $\mu mol \cdot m^{-2} \cdot s^{-1}$ or $\mu mol/m^2$-s. The PPF and PPFD are often used interchangeably and debate continues among plant scientists and engineers about which term is "correct." To avoid ambiguity, concentrate on the unit; if m^2 is included, then the value refers to the intensity of PAR at a surface, which is usually measured at the top of a plant canopy. If m^2 is not included, then that refers to the total amount of light emitted from a lamp (the PPF) and not the intensity at a particular location (the PPFD). Photosynthetic photon flux density is easily measured by a quantum sensor.

Photon efficiency or photosynthetic photon efficiency refers to the efficiency of a lamp at converting electricity into photons of PAR. Efficiency is output divided by input. The output of the fixture is $\mu mol \cdot s^{-1}$ of PAR. The input to the fixture is watts of energy. Since a watt is a rate of energy flow, it is equal to a joule (J) per second. The seconds in the numerator and denominator cancel and the unit becomes µmol/J. This value is increasingly being reported by plant lighting manufacturers and academics, with higher numbers representing more efficient lamps for plant applications (for more information, see http://flor.hrt.msu.edu/assets/Uploads/Footcandles-lux-lumens2.pdf).

Luminous efficiency is the number of lumens emitted per watt of energy. (One lumen per square meter equals one lux, and there are 10.8 lux per foot-candle.) This value refers to the efficiency of a lamp at emitting light visible to people and thus, is not relevant for plant applications. It is only relevant when comparing the energy efficiency of lamps for human applications such as office or home lighting.

Color rendering index (CRI) refers to how well a light source reveals the colors of various objects compared with a natural (or ideal) light source. Once again, this metric is irrelevant for plant applications. However it can be relevant when people need to interface with the plants. The highest CRI value is 100 (daylight), white LEDs have values >90, high-pressure sodium lamps have a CRI of 24, while some lamps can emit light with a negative CRI value. A low CRI value means that plants many not appear green and ripe tomatoes may not appear red. It can also be uncomfortable to work in a light environment with a low CRI.

Correlated color temperature (CCT) is the color appearance of light emitted by a lamp measured in degrees Kelvin (K). Lamps with a CCT below 3,200 K are considered warm (more red in color) while those with a CCT above 4000 K are considered cool (more blue in color) in appearance. This metric is nearly irrelevant for plant applications. g

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