BY ERIK RUNKLE

An Update on LED Lighting Efficacy

In plant lighting, the efficacy (or more precisely, the photosynthetic photon efficacy) of a fixture quantifies how effectively a fixture converts electricity into light useful for photosynthesis. It is determined by the amount of photosynthetic radiation emitted, divided by the input power to produce that light.

The number of photosynthetic photons (those with a wavelength between 400 and 700 nm) emitted by a fixture is measured in micromoles per second ($\mu mol \cdot s^{-1}$), then that quantity is divided by the power demand in watts. The efficacy unit can be simplified to $\mu mol \cdot J^{-1}$.

According to data published by Jacob Nelson and Bruce Bugbee in 2014, 400-W high-pressure sodium (HPS) fixtures with magnetic ballasts have an efficacy of around 0.94 $\mu mol \cdot J^{-1}$. Many growers still use these fixtures, and older ones can have lower efficacy values, sometimes much lower. For instance, 1,000-W double-ended HPS fixtures had an efficacy of 1.70 $\mu mol \cdot J^{-1}$ while the efficacy of light-emitting diode (LED) fixtures ranged from 0.89 to 1.70 $\mu mol \cdot J^{-1}$. In other words, at that time, double-ended HPS fixtures boasted an efficacy as high as the most efficacious LED fixtures.

The efficacy of LED fixtures has increased since 2014, in some cases substantially. In May 2018, Leora Radetsky from the Lighting Research Center at Rensselaer Polytechnic Institute (RPI) in New York published a report on testing performed with various horticultural lighting fixtures, including HPS and newer model LED fixtures (visit https://goo.gl/KJsLpp for the full report).

The emission characteristics are reported for three HPS, one metal halide and 10 LED fixtures, based on one sample of each. Some of that data are presented in Table 1. Most companies have multiple LED products, and those tested aren't necessarily their most efficacious or newest fixture.

The efficacy for high-output LED fixtures ranged from 1.13 to 2.59 $\mu mol \cdot J^{-1}$, which again indicates that some LED fixtures on the market aren't as efficient as HPS fixtures with electronic ballasts. However, the two LED fixtures tested with the highest efficacy [toplighting by Philips (Signify) and P.L. Light] were approximately 50 percent more efficacious than the tested 1,000-W double-ended HPS fixtures and 92 percent more efficacious than the tested 600-W single-ended HPS fixture.

Although efficacy is an important characteristic when comparing lighting fixtures, other factors should also be considered before investing in a particular technology. In addition to efficacy, consider the light output, purchase and installation costs, operating cost (hours used and electricity rate), maintenance cost, spatial uniformity of intensity (i.e., distribution), installed electrical capacity, fixture durability and warranty, fixture shading, utility rebates, customer service, and light spectrum from both a plant and human perspective.

The data in Table 1 also can be used to crudely estimate how many LED fixtures are needed to replace a certain type of HPS lamp. For example, a fairly new 400-W HPS lamp emits around 420 $\mu mol \cdot s^{-1}$ while a 300Lumigrow Pro 325e LED emits around 540 $\mu mol \cdot s^{-1}$. If a grower wanted to replace 400-W HPS fixtures with this Lumigrow LED fixture, they would need roughly 30 percent percent fewer LED fixtures to deliver a comparable intensity. In this case, the grower would also use about 52 percent less electricity with the LED fixtures compared with their existing HPS fixtures (compare efficacies of 0.94 and 1.80 $\mu mol \cdot J^{-1}$). However, the light output and distribution varies widely among types of lighting fixtures, so it's important to work with lighting companies to obtain a map of how many fixtures are needed, at what spacing and height, to obtain the desired light intensity and uniformity. gpn

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Fixture type	Model and rated power	Measured power (W)	Photosynthetic photon flux ($\mu mol \cdot s^{-1}$)	Photosynthetic photon efficacy ($\mu mol \cdot J^{-1}$)
HPS[1]	Sunlight Supply Sun Star, 400 W (magnetic ballast)	443	416	0.94
HPS[2]	P.L. Light SON-T PIA, 600 W (electronic ballast)	690	926	1.34
HPS[2]	Gavita Pro 1000e, 1,000 W (double-ended bulb, electronic ballast)	1,069	1,837	1.72
LED[2]	Heliospectra LX601C, 630 W	595	673	1.13
LED[2]	Hubbell Cultivaire, 425 W	358	736	2.06
LED[2]	Illumitex PowerHarvest W, 300 W	268	475	1.77
LED[2]	Lumigrow Pro 325e, 300 W	300	540	1.80
LED[2]	Philips (Signify) GreenPower Deep Red/White Low Blue, 200W	195	504	2.59
LED[2]	P.L. Light HortiLED TOP 150° Full Spectrum, 320 W	330	696	2.11
LED[3]	P.L. Light HortiLED TOP 80° Red-Blue, 320 W	313	798	2.55

Table 1. The power consumption, quantity of photosynthetic photons (400 to 700 nm) emitted per fixture, and fixture efficacy for selected high-pressure sodium (HPS) and light-emitting diode (LED) fixtures. Source: 1. Jacob Nelson and Bruce Bugbee, Utah State University, 2014; 2. Leora Radetsky, Rensselaer Polytechnic Institute, 2018; 3. Jakob Johnson, Paul Kusuma, and Bruce Bugbee, Utah State University, 2017.