Light Matters

Designing illumination systems with high-brightness LEDs

One of the most fascinating applications for LEDs is based on the interplay of light and physiology. Over the last few years, it's been the subject of over half of my papers and presentations. Physiology, in this case, isn't necessarily limited to animals. Plants can be influenced in many potentially beneficial ways.

The most obvious application of artificial light is to augment, or possibly replace, the role of sunlight in photosynthesis. Other newly-emerging applications, especially for LEDs of specific wavelengths, involve altering a plant's growth cycles (its flowering and vegetative phases) and shape.

Red light in the vicinity of 660 nm – 664 nm is very efficient for plant growth (the catalysis of CO_2 and H_2O into glucose). However most plants do not develop sufficient bulk with red light alone; they need a portion of the blue spectrum, generally between 430 nm – 455 nm. Lastly, there's a range of far-red light, from approximately 715 nm – 740 nm which is critical to many plant's capacity to synchronize their developmental phases with seasonal changes, and sense conditions of "overcrowding" by neighboring tall plants, spurring them to grow taller. The optimum proportions and timing of various wavelengths appear to be species-specific. In other words, the best "light recipe" for radish is likely to be different than the recipe for soybean.

A further question is how to quantify that light. We are accustomed to thinking of light from a "human perspective". Our eye's primary mechanisms for color perception are photoreceptors called cone cells. We have more long-wavelength (red sensitive) and medium-wavelength (green sensitive) cone cells in our eyes than short-wavelength (blue sensitive) cones. As a result, green looks "brighter" to us than an equivalent amount of energy in the blue portion of the spectrum. Other animals, especially insects, have quite different color sensitivities. But I'll leave that topic for another column. Light measurements which are normalized to our human visual response are called photometric, with common units such as lumens, candela, lux and nits.

Plants have an entirely different perspective on light. Of course there are no cone cells with characteristic sensitivities, so we do not need to normalize to a seemingly arbitrary human vision color response curve; we're free to consider the energy in the same way as the rest of the electromagnetic spectrum- radiometrically- in units like watts.

Various processes and light-gated signaling inside the plant utilize light across a range of about 400 nm to 700 nm. In botany, that particular spectral range is usually referred to as the Photosynthetically Active Radiation, or PAR. You can see in Figure 1 that PAR encompasses major absorption peaks of Chlorophyll *a* and Chlorophyll *b*.

A second distinction relates to what is most often studied with regard to light and plants – photosynthesis. Specifically, the rate of photosynthesis. The photosynthetic process is complicated, but ultimately these are sequences of chemical reactions. Some of the reactions require the absorption of a photon in the PAR region to complete. Thus, if we can "count" the number of PAR photons delivered to a plant per unit of time, we can gauge the photosynthetic rate. Assuming that light from above falls on a large portion of the chlorophyll-containing leaves, one general measurement of photosynthetic activity is the number of PAR photons per second falling on a given area of the plant surface. This is known as Photosynthetic Photon Flux. As you can imagine, that's an enormous number of photons, thus the common unit is µmols m^{-2} s^{-1} (micro-moles of photons per meter squared per second). One µmol is 6×10^{17} photons.

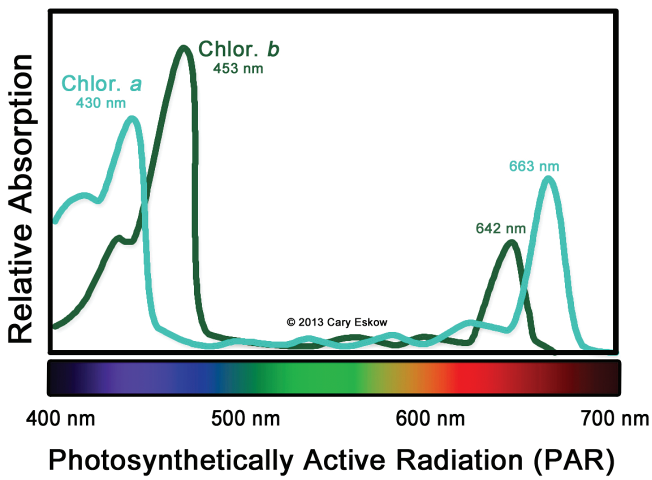

Figure 1—The PAR spectrum ranges from about 400 nm to 700 nm

Most house plants require about 50 – 200 µmols; tomatoes, strawberries and many other fruit do well with 400 – 900 µmols, etc. I live in San Diego, and on a sunny day (is there any other kind?) we receive well over 2,000 µmols of PAR. Various plants have characteristic upper limits to their photosynthetic rate, so more is not necessarily better.

LEDs are destined to influence horticulture and floriculture for several reasons. They enable us to "engineer" the light to more closely follow the peaks in Figure 1; they radiate much less heat than other PAR lighting solutions such as HID lamps; and of course they save vast amounts of energy.

Your "budding" questions and comments are always welcome. This and other Light Matters articles are downloadable at **www.em.avnet.com/LightSpeed**