IMPORTANCE OF LEDs IN HORTICULTURE

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Can broad-spectrum radiation that is obtained from the Sun and traditional horticultural lighting sources (i.e. HPS and fluorescent tubes) really be substituted by LEDs?

Simply put, yes.

LEDs in greenhouse vegetable production can better control the rate of photosynthesis, as well as many hormonal and morphological changes. By using the narrow bandwidth spectrum emitted from LEDs, plants can be provided with lights that correspond to the peaks of the photosynthetically active radiation (PAR) curve (Figure 1), where maximum plant growth occurs in the red (660nm) and blue (450nm) spectrum, and less growth in the green region. Furthermore, these peaks correspond to increased secondary metabolites concentrations in plants that are nutritious for humans. Along with higher electrical and lighting application efficiencies, LEDs represent an extremely economic and highly profitable lighting solution for greenhouse growers.

Wavelength Selection: Since the ideal wavelength range for plant growth is 420nm to 470nm (blue) and 600nm to 700nm (red), supplying them with broad-spectrum lighting is an inefficient use of energy (Papadopoulus and Pararajasingham, 1997). High power light emitting diodes (LEDs) are a versatile artificial light source offering a variety of advantages over traditional forms of horticultural lighting. Their small size, durability, longer lifespan, cool emitting temperature, and the option to select specific wavelengths for a targeted plant response, make LEDs more suitable for plant based uses than many other light sources. These advantages, coupled with new developments in wavelength availability, light output, and energy conversion efficiency, places us on the brink of a revolution in horticultural lighting (Massa et al., 2008).

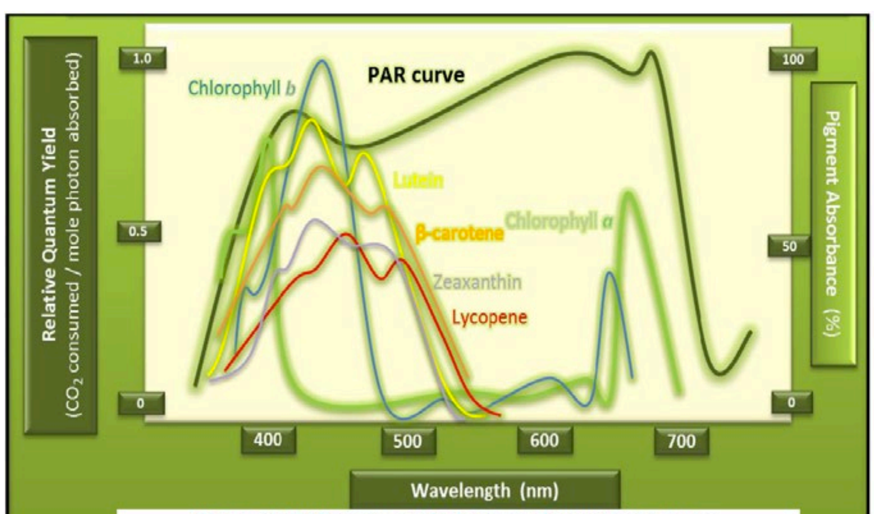

Figure 1: PAR curve and pigment absorption spectra

LED Ratio: By applying the PAR curve peaks, shining wavelengths of red light (660nm) can trigger phytochrome responses related to stem growth, photosynthetic structuring, the onset of flowering (photoperiodism), setting circadian rhythms, regulating germination of seeds, elongation of seedlings, and the size, shape and number of leaves. On the other hand, blue light (450nm) is known to trigger cryptochromes that are linked to the regulation of germination, elongation, photoperiodism (circadian rhythm), sensing of magnetic fields, normal chlorophyll and chloroplast development, and enzyme synthesis (Tamulaitis et al., 2005). However, the impacts of mixing different ratios of red and blue LED light intensities (x red: x blue) are still debated upon in the scientific community. While Son and Oh (2013), Lin (2000), Deram et al. (2014) and Goins et al. (1998) have said that high ratios of blue light (5:1) led to shorter stem length as well as greater flowering and fruit production, and exposure to increased red light (19:1) generates the highest plant biomass (excluding fruit), Massa et al. (2008) on the other hand states that increased levels of blue light is responsible for greater plant leaf production, without impacting flowering or fruiting. Moreover, in a study by Lee et al. (2015), blue light produced no statistical difference in leaf production, width or length but it did increase leaf thickness. White lights are generally used to monitor plant development as it provides a better view to the grower. While white LED light on its own is not as effective of a plant lighting source, supplementing white light with low levels of blue light to form warm white LEDs can increase stem elongation and leaf expansion, whereas high levels of blue light from cool white LEDs can result in more compact plants (Cope and Bugbee, 2013).

Nutritional Impact: LEDs can also impact the nutritional values of greenhouse produce. Lefsrud et al. (2008) demonstrated effects of differing wavelength and irradiance on pigment accumulation in kale. Hydroponic grown plants subjected to a range of PAR LED impacted the secondary metabolites accumulated under the different treatments, including chlorophylls, lutein and β-carotene and glucosinolates (antioxidants). It was seen that metabolite accumulation concentrations varied between wavelength treatments, with accumulation peaks at 640 and 440 nm, which also corresponded with the two highest irradiance values. Similarly, Urbonavičiūtė et al. (2009) have noted that compared to HPS, LEDs can promote the synthesis of antioxidative compounds, such as vitamin C, phenolic compounds and carotenoids on certain plants such as wheatgrass, barley grass, and leafy radish.

Irradiance: Crop productivity is affected by the position of the light sources with respect to the photosynthetic surfaces as this affects the incident light intensity that they receive. Since the radiation energy intercepted by a surface from a point source is proportional to the inverse square of the distance between them (Bickford and Dunn, 1972), reducing that distance will have a large impact on the incident light level. Compared with intensely hot, high-intensity discharge emitters which have an efficiency of ≈25%, LED lamps operate at efficiencies of ≈40% which creates lower operational temperatures, more directed heat sinks and allows for the lights to be brought much closer to plant tissues. LEDs, therefore, can be operated at much lower energy levels to give the same incident photosynthetic photon flux at the leaf surface (Massa et al., 2008). This allows LEDs to be designed not only as overhead lights, but also as intercanopy lighting devices as well, ensuring maximum plant productivity and yield. Additionally, wide spectrum beams also have a tendency to bounce off greenhouse surfaces, leading to higher rates of diffusion and overall inefficiency. This is mitigated is overhead LED fixtures, as the light can be easily converged, and the effect is reduced even further in intercanopy LED use. Research from Cornell University on has shown that 250μmol.m-2.s-1 of light (≈22mol.m-2.day-1) is ideal to maximize the production of lettuce in a greenhouse located in Northeaster North

America (Brechner and Both, n.d.). The use of lamps that provide 150-250µmol.m-2.s-1, will meet these requirement as either overhead or intercanopy lighting. Moreover, Ouzounis et al. (2015) states that due to the precise light delivery mechanism of LEDs, overhead fixtures delivering at least 250µmol.m-2.s-1 (up to 500µmol.m-2.s-1) can reduce the growth time of greenhouse tomatoes and lettuce.

Much of our current understanding of LEDs has proven it to be a competitive light source for greenhouse applications. Although opinion in the scientific community is divided regarding the optimum red to blue wavelength ratios for pursuing different plant growth strategies, there is a large support for using higher levels of blue light (1:1) to promote early and increased fruiting whilst creating a more compact plant with thicker leaves. Meanwhile, a 6:1 ratio promotes leaf and fruit production, leading to a balanced growth. Mixing red and blue wavelengths at a 3:1 ratio is the most popular greenhouse practice to create a more neutral growth regime, with research supported by Schwalb (2013) who noted a transition point from a low to high photosynthesis rate for both tomato and lettuce at a 4:1 ratio. Based on studies from Ste. Anne-de-Bellevue (QC) and Cornell (NY), for greenhouse applications at least 250µmol.m-2.s-1 is suggested for overhead LED fixtures with 70µmol.m-2.s-1 to 125µmol.m-2.s-1 (Deram et al., 2014) of intercanopy lighting to supplement it.

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