Samsung Horticulture LEDs

Nov. 2018

Lighting for Horticulture

The objective of artificial lighting is to efficiently deliver the proper type and appropriate amount of illumination for stimulating plant growth and nurturing its development. Various artificial light sources such as metal-halide, high pressure sodium, and fluorescent lamps have been generally used for plant cultivation. Some of their disadvantages have included inefficient energy usage, a short lifetime for the lighting selected and difficult-to-control wavelengths arising from photosynthesis and morphogenesis. The use of light-emitting diodes (LEDs), however, is now being considered the most promising approach to lighting optimization for horticulture tasks.

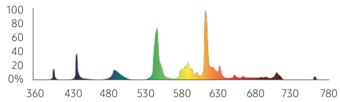
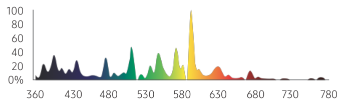
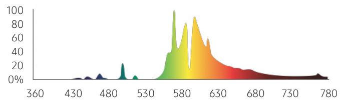
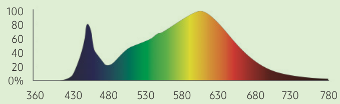
	Spectrum	Controllability	Design Flexibility	Efficacy (μmol/J)	Warm-up Time	Heat	Lifetime (hrs)
Fluorescent		Low	Low	1.0	Short	Low	< 20,000
MH		Low	Low	1.4	Long	High	< 20,000
HPS		Low	Low	1.8	Long	High	< 30,000
LED		**High**	**High**	**> 2.5**	**Short**	**Low**	**> 50,000**

Figure 1. Comparison of horticulture light sources

The spectral engineering wavelengths produced by LED lighting are playing an important role in enhancing plant growth and development. That's because plant physiology and morphology are strongly influenced by the wavelength optimization impacting a plant's surface. The latest comparison of horticulture lighting is demonstrated in Fig. 1.

LEDs for Horticulture Lighting

Optimizing LED lighting for the horticulture industry is still in its infancy. An optimal strategy for using high-quality LED lighting in horticulture would be to select the best spectra for a specific crop or cultivar, one that offers improved quality in the most energy-efficient way. Photosynthetic responses are generally similar among the various types of plants, at least when considering quantum yield, while a morphological response seems to be more species- and cultivar-specific.

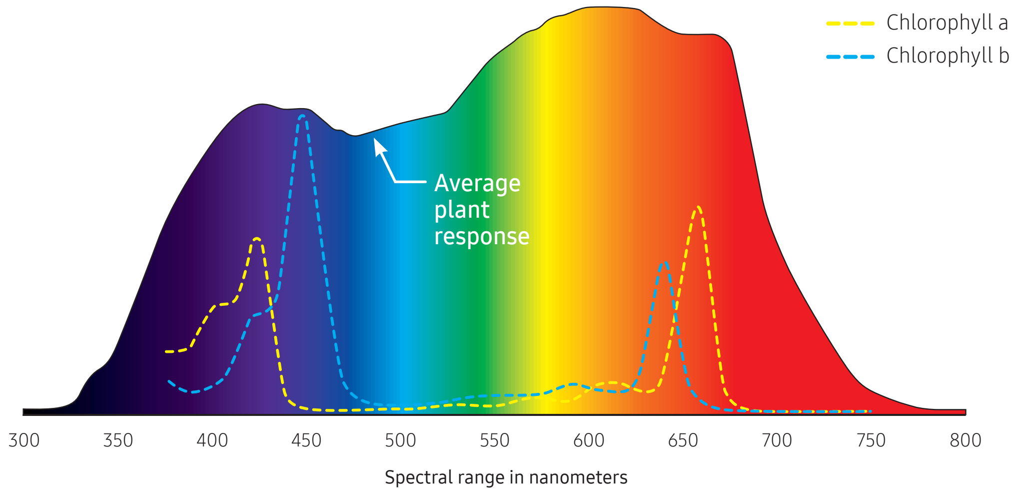


Figure 2. Chlorophyll absorption and photosynthetic response to absorbed photons at different wavelengths

Red and blue lights fit with the absorption peak of chlorophylls involved in photosynthesis, as illustrated in Fig. 2 [1]. Red radiation is often considered the most efficient at driving photosynthesis based on the quantum yield. Blue light, however, is essential for both the vegetative and flowering stages of plant growth. Until now, these functions have made for a conventionally narrow horticulture spectrum by simply employing a combination of blue and red lights – an approach widely used in Europe.

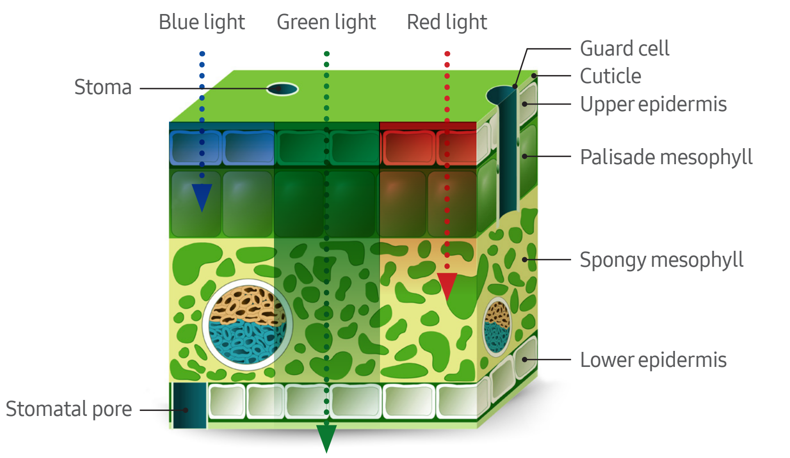


Figure 3. Schematic showing of monochromatic blue, green and red light through a leaf

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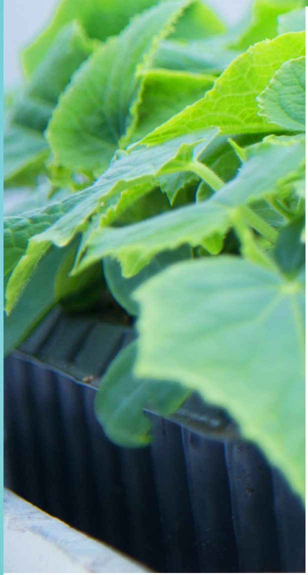

Even though the dissolved chlorophyll (a and b) absorbs most of the photosynthetic benefits that were lost in the red and blue regions of the spectrum, and more weakly in the green area, we have found that red, then green, followed by blue light are most effective in photosynthesis, based on the quantum yield for CO_2 fixation on leaves. This is referenced in the McCree curve as seen in Fig. 2 [2]. Green light can penetrate deeper than blue or red light in the plant canopy due to its high transmittance, allowing light to reach the lower branches and leaves of the plant, as shown in Fig. 3 [3, 4]. Green light is also involved in a reverse defense mechanism that can be triggered by blue light, which influences flowering and morphogenesis [5, 6]. The influence of each wavelength region on photosynthesis is described in Fig. 4.

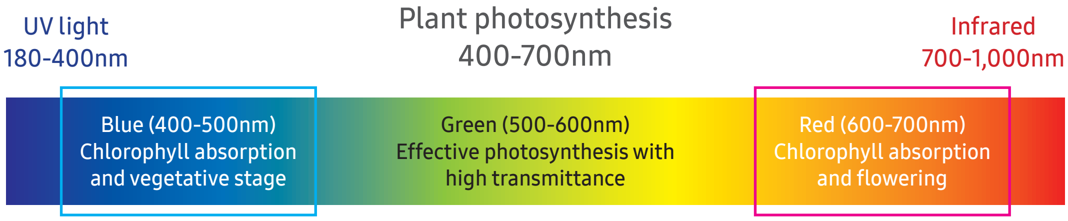

Figure 4. Wavelength effects on plant growth

Samsung has made several attempts to develop new spectrum for horticulture lighting. One solution is to utilize white LED alone or in conjunction with monochromatic LEDs to create a very broad spectrum. These approaches using Samsung white LEDs can deliver the full spectrum of light to promote plant growth, as well as comfortably perform cultivation management, with even better color rendering (Fig. 5).

Figure 5. Plant factory with narrow (left) and full (right) spectrum lighting

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Samsung has developed several lighting solutions for use in the cultivation of crops. Spectral science trials have been conducted for leafy greens and herbs with the purpose of improving plant growth and quality. Leafy greens are commonly eaten as a vegetable. Among the many popular species of edible leafy greens are lettuce, butter head, and oak leaf. On the other hand, herbs have distinct aromatic properties and are widely used for flavoring. Examples include basil, rosemary and oregano (Fig. 6). We investigated the influence of the lighting spectrum on lettuce and basil, two of the most widely consumed plants. A series of experiments were conducted, upon the advice of Professor Changhoo Chun, an expert in the field, from Seoul National University, Korea.

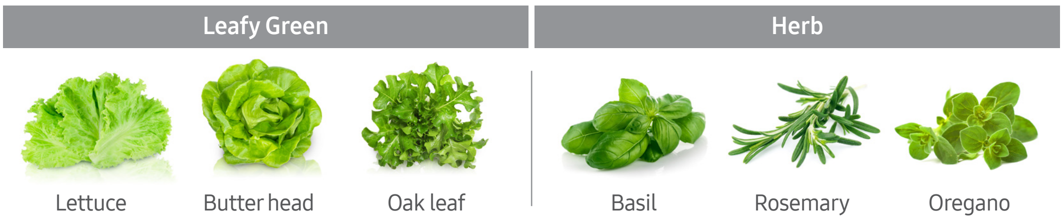

Figure 6. Various species of leafy greens and herbs

Lettuce and basil were grown in curtained chambers under white LED-based full spectra, and with narrow spectra using only blue and red LEDs (Fig. 7). Photoperiod of all the treatments was 16 hours/day and PPFD was set at 160 μmol*m^2/s. Each PPFD ratio of the various lighting treatments is listed in Table 1.

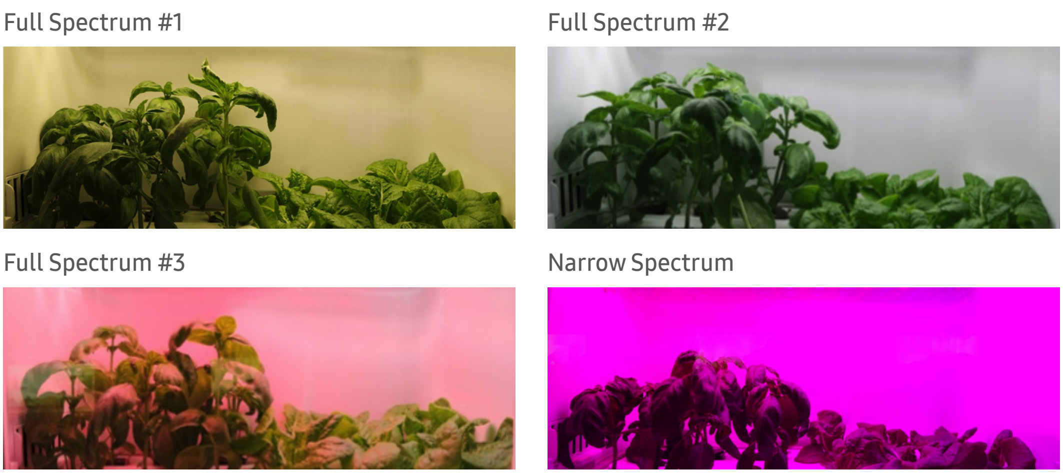

Figure 7. Growth chambers under 4 light conditions

	Blue	Green	Red
Full spectrum #1	1	4	4
Full spectrum #2	1	2	2
Full spectrum #3	1	2	12
Narrow spectrum	1	0	4

Table 1. Photosynthetic Photon Flux Density (PPFD) ratio of various light treatments

The results show that the Samsung broad spectra treatments outperformed the narrow ones, using comparative fresh weights (Fig. 8). This implies that the addition of light colors such as green and yellow, or ‘full-spectrum’ lights, produces better results than dual-colored (blue and red) lights. Our testing showed that green light can not only reach the bottom layer of leaves and branches due to its high transmittance, but can also contribute to signaling information that reverses the defense mechanism of UV/ blue-light. Therein, by employing optimized Samsung horticulture spectrum, plant yields can be boosted significantly.

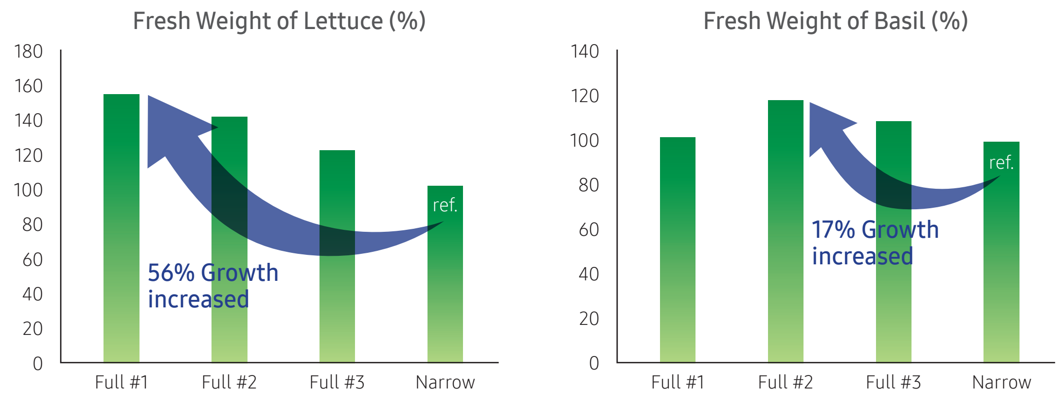

Figure 8. Performance of narrow and full LED spectrum

The newly designed Samsung Horticulture Lighting is available with two distinct options – using only White-based full spectrum or in a White+single wavelength combination. The White-based full spectrum delivers increased plant growth as well as being pleasing to the human eye, while suiting a broader range of applications. The White+single wavelength combination has proven to be beneficial for several plant species grown for specified purposes. Taken together, Samsung horticulture LEDs can move well beyond the standard of horticulture lighting with the highest efficacy of 2.74 μmol/J, a dramatically extended non-yellowing lifetime, and better PPFD uniformity. Our testing also clearly shows that white-based full spectrum horticulture treatments are more economically viable than solutions using any conventional narrow spectrum. Furthermore, a Samsung SMART-Farm System will be coming soon to enable growers to automate their spectral schedules in ways that optimize their horticulture businesses.

[1] Renger G., Irrgang K., Singhal G., “Concepts in Photobiology: Photosynthesis and Photomorphogenesis", New Delhi (1999).

[2] McCree and Keith J, "The action spectrum, absorptance and quantum yield of photosynthesis in crop plants", Agricultural and Forest Meteorology. (1972).

[3] Kozai N., “Plant factory with artificial light”, Ohmsya Pub (2015).

[4] Jindong S., John N. and Thomas V., "Green Light Drives CO_2 Fixation Deep within Leaves". Plant Cell Physiol. (1997).

[5] Smith L., McAusland L., and Murchie H. “Don't ignore the green light: exploring diverse roles in plant processes”, Journal of Experimental Botany (2017)

[6] Silvia F., Lawrence T., Roberto B. and Eduardo Z., “Reversal of Blue Light-Stimulated Stomatal Opening by Green Light”, Plant and Cell Physiology (2000).

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