Proposal of LEDs for the vertical farm

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LED Selection

Three LED components from Lumileds have been selected for the lighting system in our vertical farm. Lumileds offers LEDs with a relatively small PPF and considered that a more uniform light distribution could be achieved by deploying more of these LEDs.

We will combine white and red LEDs to get the appropriate ratio for blue light and red light, white LED also can supply green component needed for plant growth. Far Red LEDs are used to promote stem and leaf growth.

The selection of LEDs is shown below：

1. LUXEON SunPlus 2835 Lumileds Horticulture **White** (L1SP-PNK1002800000) , datasheet
2. LUXEON SunPlus 2835 Lumileds **Deep Red** (L1SP-DRD0002800000) , datasheet
3. LUXEON SunPlus 2835 Lumileds **Far Red** (L1SP-FRD0002800000) , datasheet

Product	Color	PPF (μmol/s) [1]	PPF/W (μmol/J) [1]	Viewing Angle [1]
L1SP-PNK1002800000	White	0.78	2.28	120
L1SP-DRD0002800000	Red (655-670 nm)	0.62	2.32	130
L1SP-FRD0002800000	FR (720-740 nm)	0.60	2.32	130

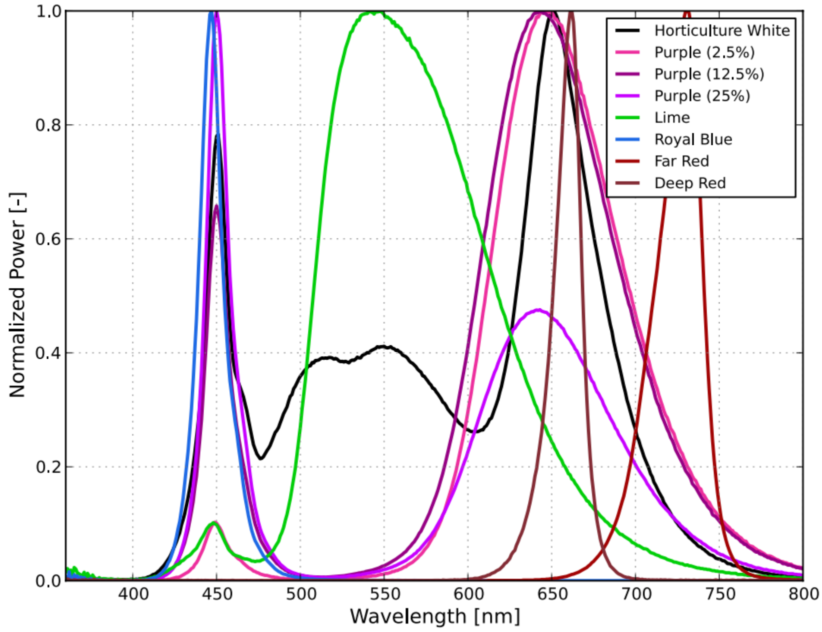

Figure 1. Spectral power distribution of white, red and far-red LEDs obtained from the datasheet

The spectrum of light emitted by the red and blue LEDs matches the spectrum well absorbed by chlorophyll [1]. The ratio of red to blue is important for crop growth and development, often requiring only a smaller number of blue photons than red photons. For example, R: B = 3:1 is good for pepper grown [2].

Green photons are also effective for photosynthesis, but green LEDs are less efficient than blue and red LEDs [3]. White LEDs, on the other hand, are relatively efficient and inexpensive. White LEDs with a spectral distribution around blue and green can therefore be used instead of blue and green LEDs.

Far-red photons promote stem and leaf growth, but at the expense of root growth and other growth, preventing flowering and fruiting [4], [5]. On the other hand, it has also been reported that a combination of 20 h photoperiod and FR light speeds up the breeding cycle of peppers [6]. Therefore, to maximize the benefits of FR, FR LEDs are used until flowering, after which the peppers are grown without FR light.

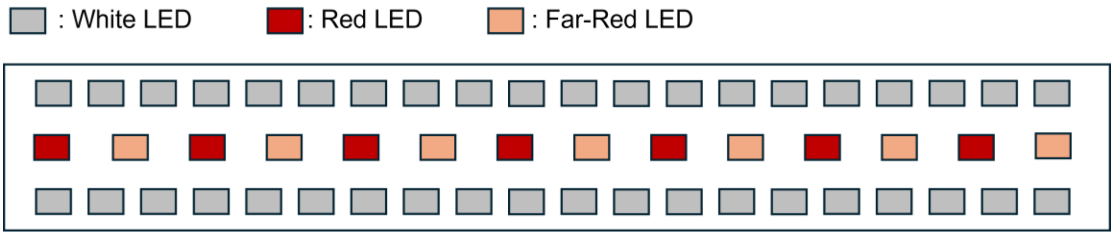

Figure 2. Example of LED arrangement

Calculations

The lighting system is designed for a planter with dimensions of 35 cm x 65 cm (0.2275 m^2). Assume the LEDs will be installed 1 m above the planter, no reflectors and covers to install on LEDs, and the target PPFD (Photosynthetic Photon Flux Density) is 250 $\mu mol \cdot m^{-2} \cdot s^{-1}$ [7]. If we can therefore only illuminate the planter, the PFD required is

250 * 0.2275 = 56.875 μmol/s

-------- Below here it may not be necessary so far... ------

To determine the number of LEDs required for each type, we use the following calculations:

Calculate the PPFD contribution from one LED at 1 m height: PPFD = PPF / Area

Calculate the number of LEDs needed to achieve the target PPFD: Number of LEDs = Target PPFD / PPFD per LED

TODO: Consider R:B ratio, the number of Red LEDs seems too much, the two combined should be 250 μmol·m-2·s-1

Lumileds Horticulture White (L1SP-PNK1002800000)

PPFD = 0.78 μmol/s / (π * (1 m * tan(60°))^2) =

Number of LEDs =

Reference

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[2] Y. Li, G. Xin, Q. Shi, F. Yang, and M. Wei, 'Response of photomorphogenesis and photosynthetic properties of sweet pepper seedlings exposed to mixed red and blue light', *Front. Plant Sci.*, vol. 13, Feb. 2023, doi: 10.3389/fpls.2022.984051.

[3] P. Kusuma, P. M. Pattison, and B. Bugbee, 'From physics to fixtures to food: current and potential LED efficacy', *Horticulture Research*, vol. 7, p. 56, Jan. 2020, doi: 10.1038/s41438-020-0283-7.

[4] S. Demotes-Mainard *et al.*, 'Plant responses to red and far-red lights, applications in horticulture', *Environmental and Experimental Botany*, vol. 121, pp. 4–21, Jan. 2016, doi: 10.1016/j.envexpbot.2015.05.010.

[5] S. Chen, L. F. M. Marcelis, and E. Heuvelink, 'Far-red radiation increases flower and fruit abortion in sweet pepper (*Capsicum annuum* L.)', *Scientia Horticulturae*, vol. 305, p. 111386, Nov. 2022, doi: 10.1016/j.scienta.2022.111386.

[6] H. Choi *et al.*, 'Development of a speed breeding protocol with flowering gene investigation in pepper (Capsicum annuum)', *Front. Plant Sci.*, vol. 14, Sep. 2023, doi: 10.3389/fpls.2023.1151765.

[7] H. Hwang, S. An, M. D. Pham, M. Cui, and C. Chun, 'The Combined Conditions of Photoperiod, Light Intensity, and Air Temperature Control the Growth and Development of Tomato and Red Pepper Seedlings in a Closed Transplant Production System', *Sustainability*, vol. 12, no. 23, Art. no. 23, Jan. 2020, doi: 10.3390/su12239939.