

Light Matters: Effect of Light Spectrum on Leafy Vegetables

LED lights significantly enhance the growth of edible leafy vegetables by boosting photosynthesis and controlling growth cycles. A good “light recipe” maximizes production with least energy input. Factors to consider are *well-designed light source, appropriate light spectrum, light intensity, uniformity, light/dark period, lighting direction, and distribution*.

Recap of “Tips for Choosing the Right Lights” newsletter:

PAR

Photosynthetic Active Radiation (PAR): Visible light (made up of elementary particles call photons) within the 400-700 nanometers wavelength spectrum that are most required for photosynthesis. Different crops at various stages of its life cycle require different combination of spectrum to optimise for yield and health.

PPFD

Photosynthetic Photon Flux Density (PPFD, $\mu\text{mol}/\text{m}^2\cdot\text{s}$): measures how many PAR photons are landing per square metre. PPFD differs depending on how far away from the lighting system measurements are taken.

DLI

Daily Light Integral (DLI, $\text{mol}/\text{d}\cdot\text{m}^2$): measures the total amount of light in the PAR spectrum that is delivered to a plant every day.

Conversion between PPFD & DLI

$$DLI(\text{mol}/\text{d}\cdot\text{m}^2) = \frac{\text{photoperiod} \times PPFD \times 3600}{1,000,000}$$

Photoperiod and PPFD

Photoperiod is the length of time each day that a plant is exposed to light. For most leafy vegetables grown indoors, an average light level (PPFD) of 100–300 $\mu\text{mol}/\text{m}^2\cdot\text{s}$ for 10–18 hours daily can be applied. For example, lettuce needs a DLI of 12–17 $\text{mol}/\text{d}\cdot\text{m}^2$. To achieve a DLI of 12 $\text{mol}/\text{d}\cdot\text{m}^2$, you can use a PPFD of 300 $\mu\text{mol}/\text{m}^2\cdot\text{s}$ for 11 hours or 210 $\mu\text{mol}/\text{m}^2\cdot\text{s}$ for 16 hours.¹

Light spectrum and its quality on the growth of leafy vegetables

Red and blue light (5–30% of blue light and 70–95% of red light) or a whitish light with even-distributed peaks are commonly used in vertical farming to grow leafy vegetables. However, plants still require other colours of light. This newsletter introduces the other less common light spectrums such as **green and far-red light**, and how they can improve the yield of leafy greens.

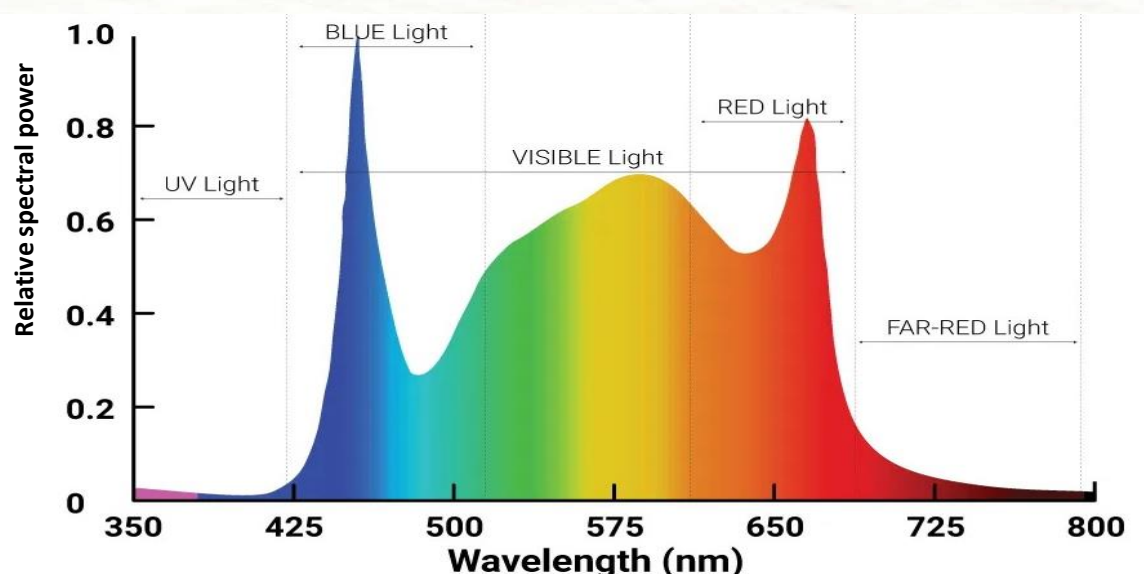


Figure 1: Voltgrow²

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PAR and Wavelength spectrum

The visible light spectrum used for plant growth primarily involves the following wavelengths:

- **Blue light (400-500 nm):** Crucial for vegetative growth, strong root development, healthy leaf formation, and overall structural integrity.
- **Green light (500-600 nm):** Penetrates deeper into the plant canopy than blue and red light. This contributes to photosynthesis in lower leaves and effective in producing dense canopy of plants.
- **Red light (600-700 nm):** Efficient in photosynthesis (i.e. how a plant converts light energy into chemical energy, typically measured by the plant's biomass). It promotes flowering, bud formation, and fruit production.

Far-Red (FR) Light³

Far-red light (700-800 nm): Impacts plant growth by:

- 1. Triggering Shade Avoidance:** Induces stem and leaf elongation, increases leaf expansion and upward leaf orientation to outcompete neighbours for light.
- 2. Increasing Biomass:** Boosts overall biomass production through improved light capture and utilization.
- 3. Inducing Morphological Changes:** Causes stem lengthening, leaf area increase, and internode elongation to optimize light capture.

Case Study 1

Optimizing LED Lighting for Xiao Bai Cai: Preliminary Findings from SFA's collaborative project with Wageningen University and Research

Early observations:

- 1 Extending the photoperiod, rather than increasing LED light intensity, led to higher vegetable yields.
 - E.g. increasing the photoperiod from 12 to 18 hours, while reducing the light intensity by 33%
- 2 Introducing far-red (FR) light during the last quarter of the growing cycle significantly increased harvest yield.
 - Adding FR light in the last week before harvest had the same increase in yield as compared to adding FR light throughout the growing cycle.

Case Study 2

Effect of Green and Far-Red (FR) light ratios on yield of Lettuce and Kale⁴

LED light spectrum

Red light was delivered at 120 $\mu\text{mol}/\text{m}^2\cdot\text{s}$ in all treatments while the remaining 60 $\mu\text{mol}/\text{m}^2\cdot\text{s}$ was comprised of Blue, Green, and/or FR light.

Cultivars

- Green butterhead lettuce 'Rex'
- Red oakleaf lettuce 'Rouxai'
- Kale 'Siberian'

Growing System

Deep-flow hydroponic system

Substrate

Rockwool cubes

Temperature

20°C

Photoperiod

20 hours

DLI

13 $\text{mol}/\text{d}\cdot\text{m}^2$

Growing Cycle

30 days



Green butterhead lettuce 'Rex'



Red oakleaf lettuce 'Rouxai'

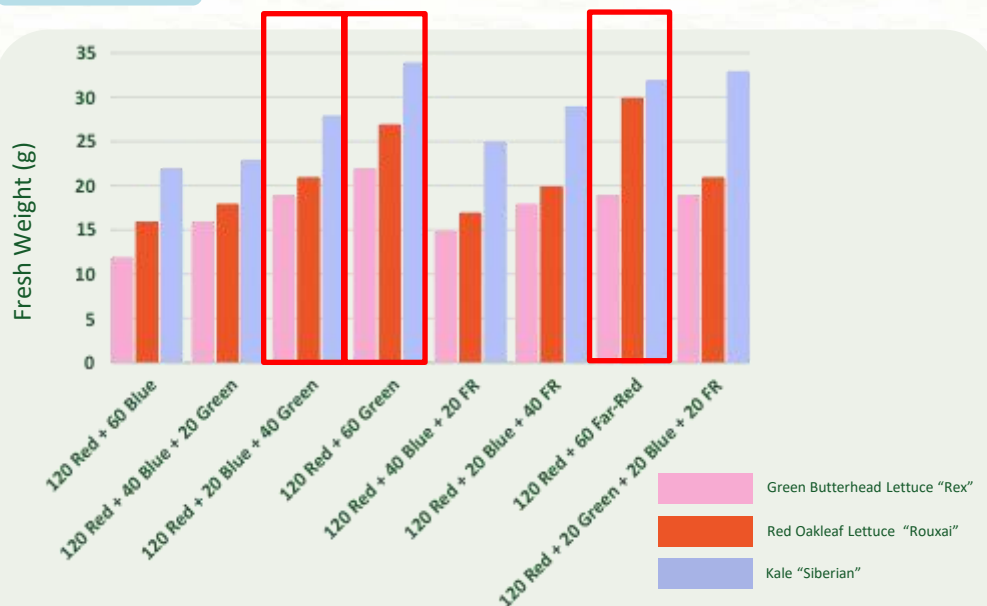


Kale 'Siberian'

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Case Study 2

(Continued from page 2) Effect of Green and Far-Red (FR) light ratios on yield of Lettuce and Kale⁴



Numbers represent the light intensity of each light spectrum ($\mu\text{mol}/\text{m}^2\cdot\text{s}$)

Fresh weight represents destructured harvest of lettuce and kale

Key Takeaways:*

- Introducing Green or FR light into the light recipe or substituting Blue Light for Green or FR light increased shoot fresh mass of all crops.[#]
- Crops with a mixture of Red, Blue and Green light had increased yield as compared to crops that grew under Red and Blue light only.
- Replacing Blue light with **FR light** also had **significant increase in yield of Red Oakleaf Lettuce "Rouxai"**.
- Replacing blue light with **green light** led to a **significant increase in yield for Kale "Siberian"**.
- For **Green Butterhead Lettuce "Rex"**, there was a **higher yield under Red + Green light** as compared to Red + FR light.



➤ The boost in yields can be at least partially explained by greater leaf expansion, which improves light capture for photosynthesis.

*It is important to note that this could differ based on different vegetable species and cultivars.



Find out more!

The Singapore Food Agency (SFA) had recently announced the \$70 mil Agri-food Cluster Transformation (ACT) Fund 2 which supports capability development, productivity improvements, and infrastructure upgrades. Farms can leverage on the Capability Upgrading component of ACT Fund 2 to adopt energy-efficient equipment and technologies from SFA's pre-qualified list. This will help farms improve energy efficiency and manage production costs to strengthen long-term resilience.

Let us know your thoughts



About the Author

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3. Zhen, S., & van Iersel, M. W. (2017). Far-red light is needed for efficient photochemistry and photosynthesis. Journal of Plant Physiology, 209, 115-122.
4. Meng, Q., Kelly, N., & Runkle, E. S. (2019). Substituting green or far-red radiation for blue radiation induces shade avoidance and promotes growth in lettuce and kale. Environmental and experimental botany, 162, 383-391.