# Light Matters: Effect of Light Spectrum on Leafy Vegetables

Singapore Food Agency

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, µmol/m²·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, mol/d·m² ): measures the total amount of light in the PAR spectrum that is delivered to a plant every day.

### Conversion between PPFD & DLI

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

**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 µmol/m²·s for 10–18 hours daily can be applied. For example, lettuce needs a DLI of 12–17 mol/d·m² . To achieve a DLI of 12 mol/d·m² , you can use a PPFD of 300 µmol/m²·s for 11 hours or 210 µmol/m²·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.

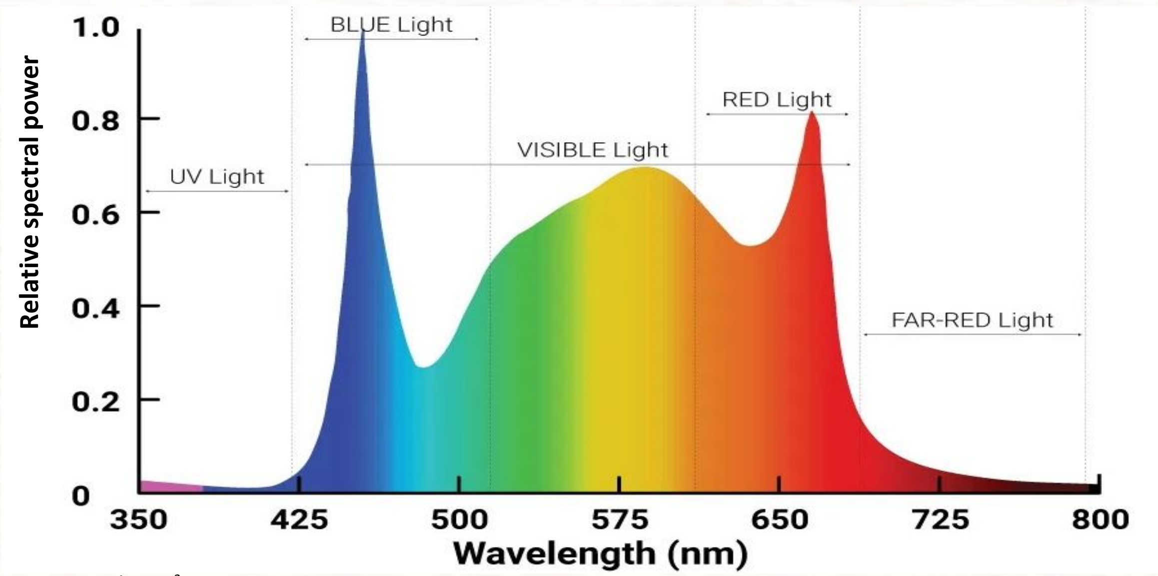


*Figure 1: Voltgrow*[2]

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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) Light[3]

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 Kale[4]

**LED light spectrum**

Red light was delivered at 120 μmol/m²·s in all treatments while the remaining 60 μmol/m²·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 mol/d·m²

**Growing Cycle**
30 days

Green butterhead lettuce 'Rex'

Red oakleaf lettuce 'Rouxai'

Kale 'Siberian'

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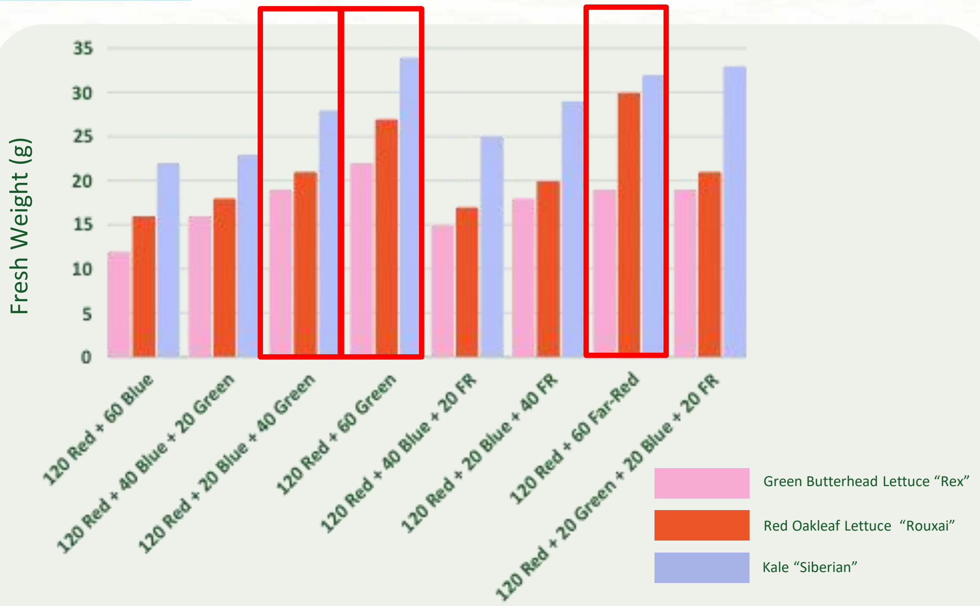
**Case Study 2**

*(Continued from page 2)* Effect of Green and Far-Red (FR) light ratios on yield of Lettuce and Kale[4]




*Numbers represent the light intensity of each light spectrum (µmol/m2·s )*
*Fresh weight represents destructed 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.

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Local farms can tap on the Agri-Cluster Transformation (ACT) Fund with the enhanced Energy Efficiency Programme (EEP) to build capabilities and capacities that help farms drive towards higher productivity in a sustainable and resource-efficient manner. Farms can tap on co-funding under the EEP to undergo an **energy efficiency audit** which would establish their baseline energy consumption and identify potential areas for improvements. Farms can also leverage the enhanced Capability Upgrading component to **adopt resource and energy-efficient equipment and technologies** from SFA's pre-qualified list. All licensed farms can apply for co-funding under the EEP.

Find out more!

**Let us know your thoughts**

https://go.gov.sg/mg2vio

**About the Author**


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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.