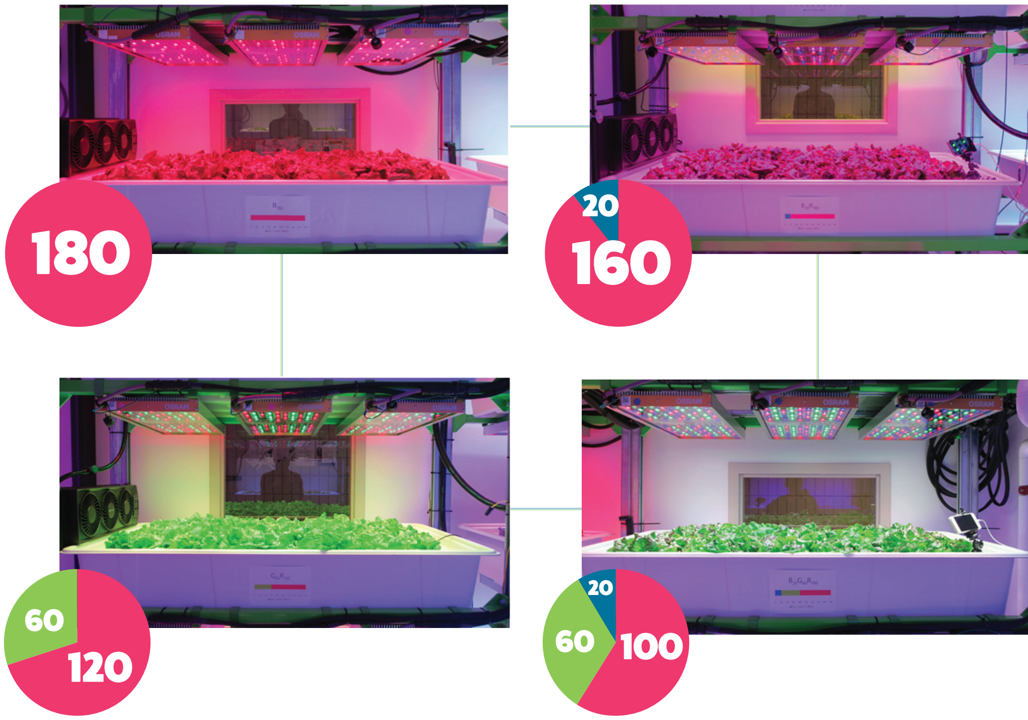


Green and blue LED lighting

By Qingwu (William) Meng & Erik Runkle

Indoor production of leafy greens, **Part II:** How green light affects lettuce growth can depend on blue and red light.

In this second article of a four-part series, researchers from Michigan State University share science-based information about indoor production of leafy greens and herbs. To read part one, click **bit.ly/green-far-red-led-lighting**

In the previous article, we cleared up some misconceptions about green (G; 500–600 nm) light to underscore its usefulness in crop production. Substituting G light for blue (B; 400–500 nm) light under a fixed intensity of red (R; 600–700 nm) light increased leaf expansion and shoot biomass of lettuce and kale. However, because G and B light can have opposing effects on growth processes, it was unclear whether the increased growth was caused by increasing G light, decreasing B light or both. We performed a follow-up indoor experiment on red-leaf lettuce to separate these two factors and better understand their roles in crop

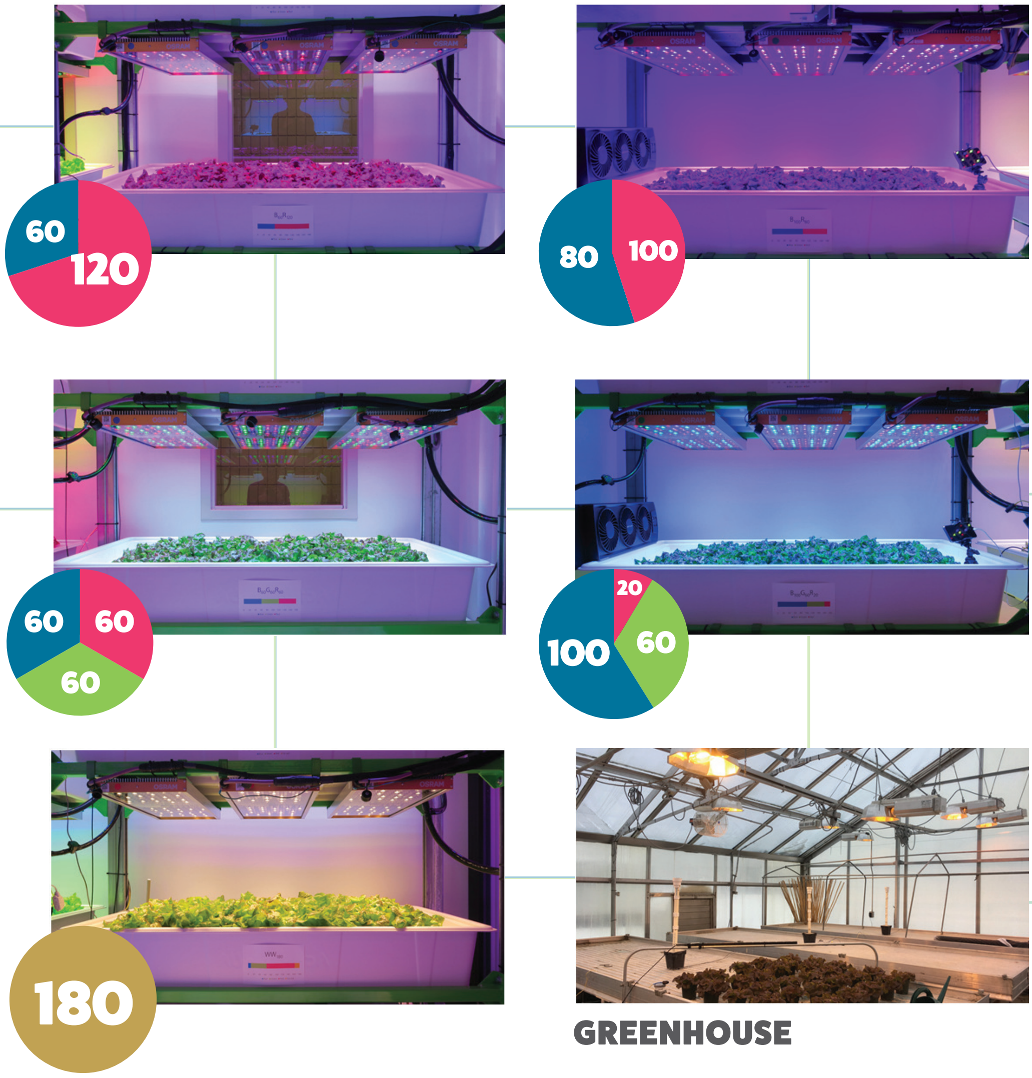
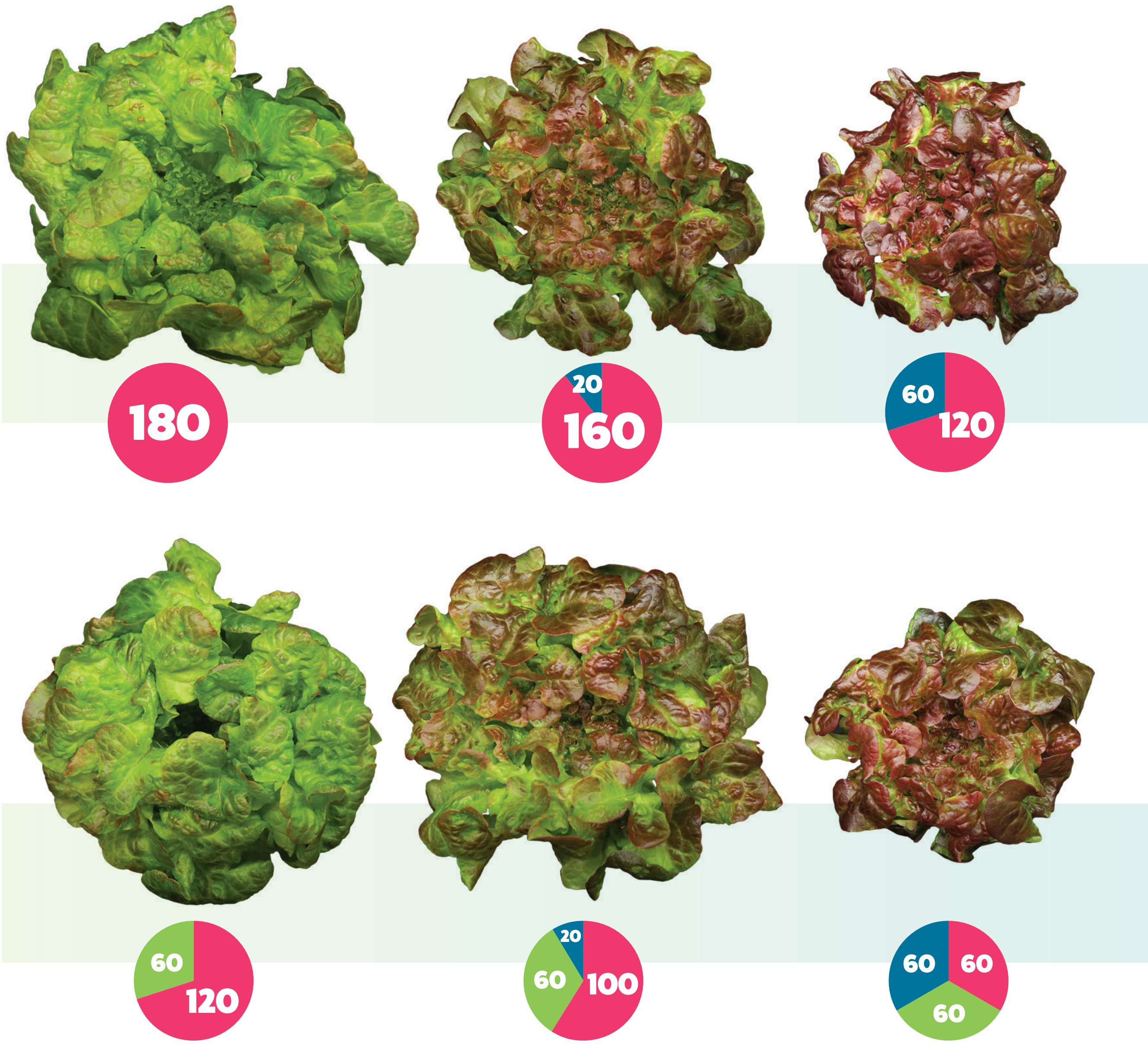


Fig. 1. Lighting treatments included eight combinations of blue and red light without or with green light, warm-white light (bottom left), or sunlight supplemented with high-pressure sodium lamps in a greenhouse. The number for each color of light indicates its intensity in μmol·m^{-2}·s^{-1}.

growth and quality attributes.

We grew red oakleaf lettuce 'Rouxai' in the Controlled-Environment Lighting Laboratory (**goo.gl/zM4bDh**). Seeds were sown in a rockwool substrate sheet and germinated at 68° F under continuous lighting from warm-white light-emitting diodes (LEDs) at 50 μmol·m^{-2}·s^{-1} (400–800 nm). After the first 24 hours, lettuce seedlings were grown at 72° F under a 20-hour photoperiod from warm-white LEDs at 180 μmol·m^{-2}·s^{-1} (400–800 nm). On day four, plants remained under warm-white LEDs or were transferred to eight different lighting treatments with the same photoperiod and light intensity, creating a daily light integral of approximately 13 mol·m^{-2}·d^{-1}. Blue+red light was delivered at 0+180, 20+160, 60+120, or 100+80 μmol·m^{-2}·s^{-1} with or without a substitution of R light with 60 μmol·m^{-2}·s^{-1} of G light. The peak wavelengths for the three wavebands were 449 nm (B), 526 nm (G) and 664 nm (R). Light combinations and schedules were delivered by OSRAM PHYTOFY RL LED fixtures and control software.

On day 13, plants under B, G and/or R light were transplanted into an indoor deep-flow-technique hydroponic system, whereas those under warm-white LEDs were transplanted into the hydroponic system or transferred to a greenhouse (**Fig. 1**). The greenhouse plants were then transplanted in a peat-based substrate and grown at 72° F under a 16-hour photoperiod from sunlight supplemented with high-pressure sodium lamps. Although we tried to create similar environments to compare indoor- and greenhouse-grown lettuce,



variables other than the spectrum existed (such as the photoperiod, daily light integral, and growing method). Growth and morphological data were collected on day 33 and 30 in two replications, followed by consumer sensory tests (with 164 panelists) and elemental analysis. Photographs of representative plants from each treatment are shown in **Fig. 2**.

Increasing B light from 0 to 100 $\mu mol \cdot m^{-2} \cdot s^{-1}$ decreased shoot fresh and dry mass regardless of G light (**Fig. 3**). Shoot mass was similar under warm-white light and G+R light. Greenhouse-grown lettuce had similar shoot mass as lettuce grown indoors with 100 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of B light. Effects of a partial substitution of R light with 60 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of G light on shoot mass depended on B light intensity. In the absence of B light, this substitution did not influence shoot fresh or dry mass. At 20 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of B light, it increased shoot fresh mass but did not affect shoot dry mass. At 60 or 100 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of B light, it decreased shoot fresh and dry mass. Plant and leaf size decreased with increasing B light, but were barely affected by G light (**Fig. 2**). In contrast to the previous article, G light generally did not increase lettuce growth or leaf expansion under fixed B light.

There are two main implications from these results. First, effects of G

Fig. 2. 33-day-old red oakleaf lettuce 'Rouxai' grown under the ten lighting treatments described in **Fig. 1.**

light should be specified within a context, which is how G light is included in a spectrum and to what spectrum it is compared. For example, G light promoted lettuce growth when substituted for B light under fixed R light, but not when substituted for R light under fixed B light. Second, the increased growth with increasing G light and decreasing B light in the previous article was mostly attributed to decreasing B light, rather than increasing G light. This is not to discount contributions of G light to photosynthesis. Instead, consider if and how the inclusion of G light changes the balance of the three wavebands (B, G, and R) in photosynthesis and morphological control. For example, G light can be comparable to B light, but less efficient than R light, at driving photosynthesis. Consequently, substituting G light for B light may not affect photosynthesis, but substituting G light for R light can decrease it.

Quality attributes characterized in this study included foliage coloration, mineral nutrient concentrations and consumer sensory preference. They were generally not influenced by G light. Foliage coloration was primarily controlled by B light (**Fig. 2**). In the absence of G light, 20 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of B light saturated red coloration (or anthocyanin accumulation) of foliage directly exposed to light. In the presence of G light, the saturation intensity

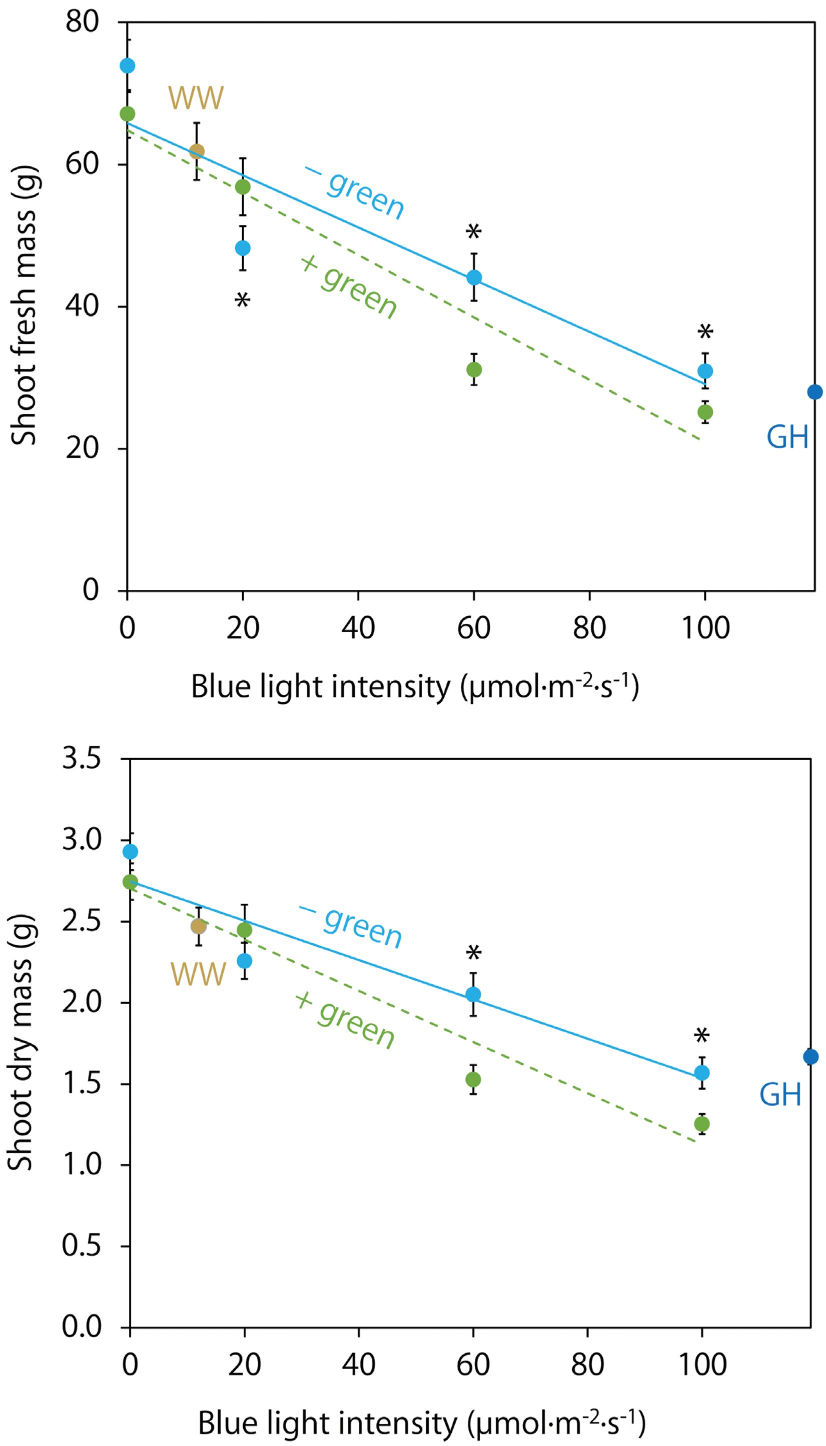


Fig. 3. Shoot fresh and dry mass of red oakleaf lettuce 'Rouxai' grown under the ten lighting treatments described in **Fig. 1**, including nine indoors and one in a greenhouse (GH). WW, warm white. The two averages (± standard errors) at each blue light intensity followed by an asterisk (*) are statistically different.

of B light was 40 μmol·m^{-2}·s^{-1}. In addition, increasing B light from 0 to 100 μmol·m^{-2}·s^{-1} increased foliar concentrations of nitrogen, magnesium, sulfur, zinc and copper by 10 to 45%, but not other mineral nutrients. Lastly, compared to greenhouse-grown lettuce, sensory panelists preferred indoor-grown lettuce, regardless of light quality. The greenhouse lettuce was more bitter and less sweet, but this could at least partly be attributed to factors other than light quality.

In summary, B light was the main driver of lettuce growth and quality attributes with or without G light. At a fixed total light intensity, effects of G light on shoot mass depended on B light intensity. Substituting G light for R light did not affect shoot dry mass under low B light (0 or 20 μmol·m^{-2}·s^{-1}) but decreased it under higher B light (60 or 100 μmol·m^{-2}·s^{-1}). In addition, what may appear to be effects of G light on crop growth could instead be caused by changes to B and/or R light. In practice, G light can be delivered, commonly through white LEDs, with low B light and high R light to improve color quality for crop inspection without decreasing yields. Because of the limited crop selection in this study, research is needed for additional species and cultivars. **pg**

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