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How to Customize your Plants with Growth Recipes – A Study with the Model Plant *Lactuca sativa* 'Diablotin'

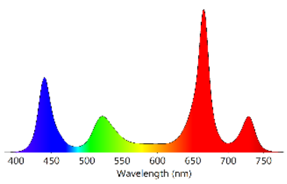
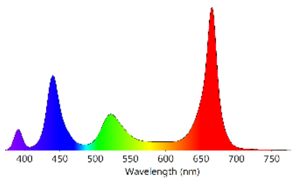
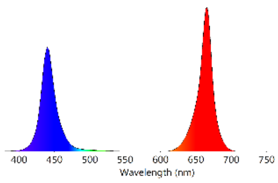
Introduction

Production of leafy greens in a controlled environment has many advantages in comparison to greenhouses and open-field production. Along with being independent of weather, controlled environments allow for easier pest prevention and crop customization. The use of plant factories has increased in the last years, both for research and commercial production (Kozai, 2013).
It is very well known that light intensity and light quality can affect plant growth. Increasing the photon flux density can result in higher biomass, better plant quality and morphology, increased secondary metabolites (Fu, Li, & Wu, 2012), and shortened production cycles. One challenge, especially for vertical farm operators, is to achieve their quality and quantity goals. Coloration is a good quality indicator, especially for red lettuce varieties. Achieving an adequate amount of anthocyanins (water-soluble plant pigments that occur in plants and give flowers and fruits an intense red, purple or blue color) and increasing yield is easier with the right growth recipes.
In OSRAM's Smart Farming Lab, a fully controllable climate chamber, we are investigating a solution for the grower's challenges. Our latest research tool, the Phytofy RL, helps us to carry out tests under different light conditions.
The objective of this study was to show how agile the Phytofy RL can be when used in the broad field of plant growth recipe research, with many diverse topics, e.g. how to improve coloration and how to affect biomass production for the red lettuce variety *Lactuca sativa* 'Diablotin' (Enza Zaden).

Materials and Methods

The plant variety used for the experiments was the red Batavia leaf lettuce *Lactuca sativa* 'Diablotin'.
Three seeds were sown per rock wool cube of 4x4x4 cm. The tray with 77 cubes was placed in a climate chamber with constant environmental conditions (Table 1). Ambient temperature and relative humidity, as well as leaf temperature, photoperiod, light intensity and carbon dioxide concentration were continuously recorded and kept to the given setpoints.

Table 1: Environmental conditions during the experimental phase in the climate chamber.

Temperature:	20/18 °C
Rel. humidity:	60-70 %
Carbon dioxide:	420 ppm
Photoperiod:	16/8 (16 hours of light and 8 hours of darkness)
Light intensity:	240 µmol·m^{-2}·s^{-1}
Spectral quality	 Full spectrum + far red  Full spectrum + ultraviolet  Red and blue (RB)

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Results and Discussion

Figure 1 and Figure 2 show the differences in the anthocyanin content as a result of the different recipes. Plants grown under full spectrum plus far red (FSFR) showed the lowest content of anthocyanins. Similar results also were shown by (Li & Kubota, 2009). They showed that UV-A and blue increased the amount of phenolic compounds, while far red led to a decrease of total phenolic compounds. The light treatment full spectrum plus UV showed the second highest content of anthocyanins, confirmed by the results from Li & Kubota, 2009. Nevertheless, red and blue showed the highest amount of anthocyanins. This shows that increasing blue and UV-A and blue light is involved in stimulating the accumulation of anthocyanins.

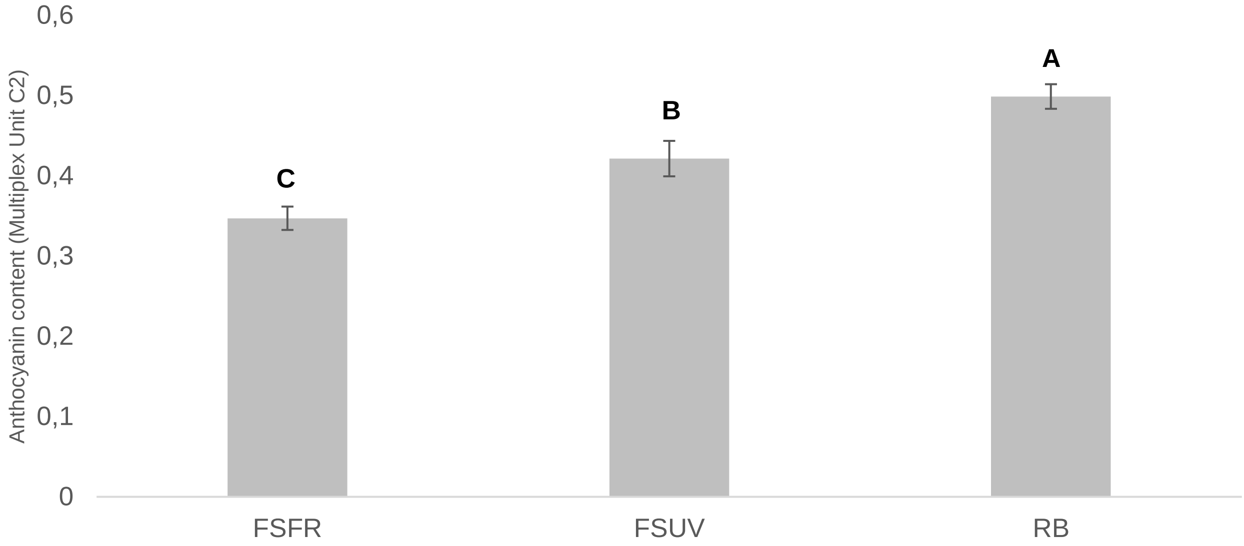

Figure 1: Comparison of mean anthocyanin content ± SEM under three different light treatments FSFR = full spectrum + far red; FSUV = full spectrum + ultraviolet; RB = red blue. (Note: Different letters represent significant differences tested by ANOVA at $p \leq 0.05$, respectively).

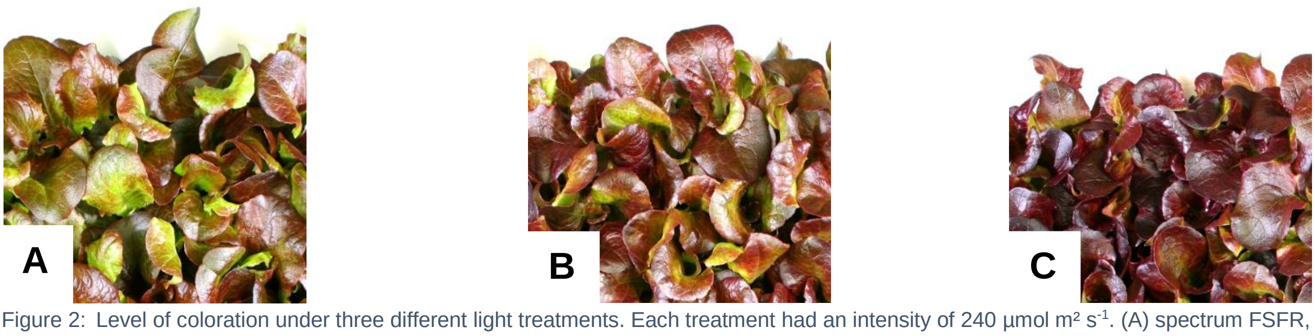

Figure 2: Level of coloration under three different light treatments. Each treatment had an intensity of 240 µmol m² s^{-1}. (A) spectrum FSFR, (B) spectrum FSUV, (C) spectrum RB.

Figure 3 presents the comparison of the mean plant fresh weight per rock wool cube. The mean fresh weight under the light treatments RB and FSUV are comparable and not significantly different from each other. However, the light treatment FSFR showed a significant increase of fresh weight. In comparison to the RB and FSUV treatments, the fresh weight increased by almost 26 percent under the FSFR treatment. This confirms the results from (Lee, Son, & Oh, 2016). They have shown that far red, in addition to red and blue, resulted in an increased fresh weight of lettuce. With OSRAM's full spectrum, enriched with far red, a significantly higher amount of fresh weight is achievable.

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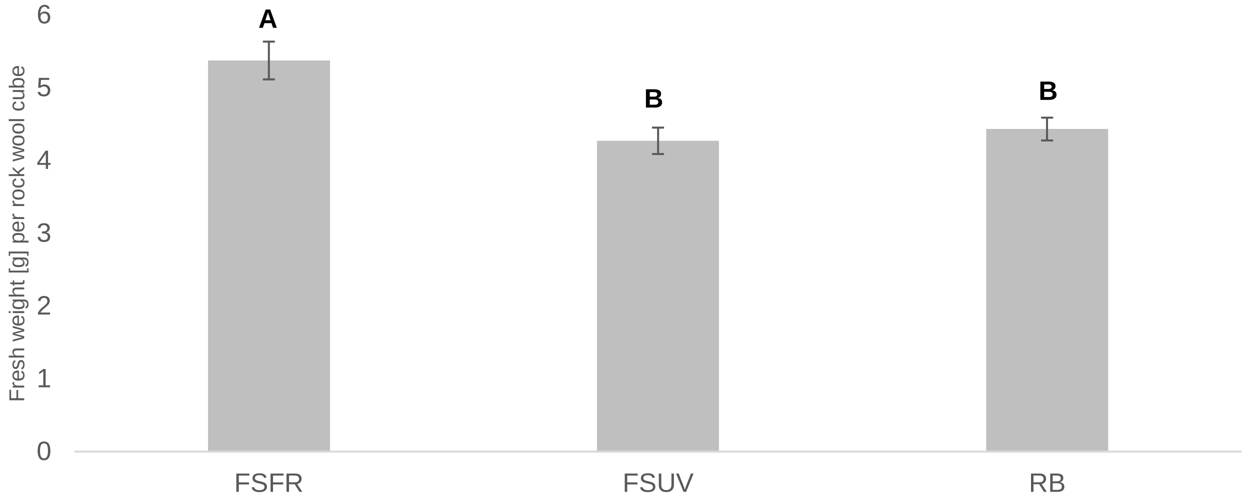

Figure 3: Comparison of mean fresh weight per rock wool cube ± SEM under three different light treatments. RB = red blue; FSFR = full spectrum + far red; FSUV = full spectrum + ultraviolet. (Note: Different letters represent significant differences tested by ANOVA at $p \leq 0.05$, respectively).

Figure 4 shows the size of the plants. Plants illuminated with only RB were the most compact followed by those which were irradiated with a full spectrum and additional UV. The biggest plants were found under the light treatment with a full spectrum and additional far red, validating the results from (Lee, Son, & Oh, 2016), which also showed that additional far red leads to a higher fresh weight and to an increase in epidermal cell size.

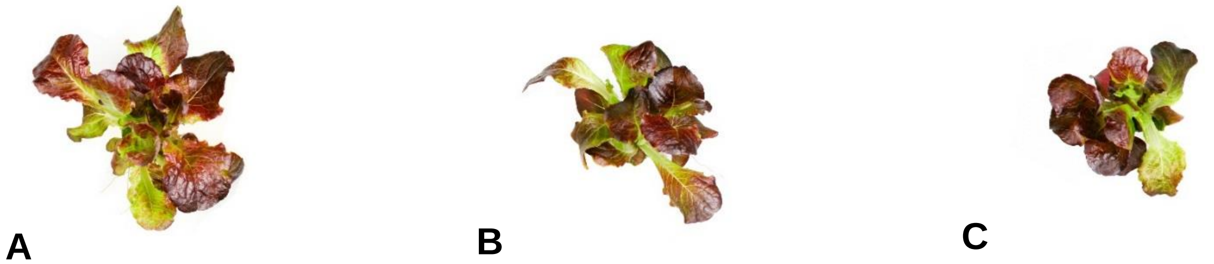

Figure 4: Comparison of plant size depending on the different light recipes. (A) spectrum FSFR, (B) spectrum FSUV, (C) spectrum RB.

Conclusions

Our results demonstrate that with OSRAM's Phytofy RL, one can customize specific plant parameters with the appropriate growth recipe. In this case, the size and coloration of red leaf lettuce are sensitive to different light recipes. With further investigation, it also can be possible to use dynamic light recipes to improve more than one parameter at a time. It is conceivable to first use a full spectrum which is enriched by far red to produce a higher amount of biomass. When this stage is complete, a recipe which improves coloration can be used for a few days as an "end of production treatment" to finalize the coloration of the plant and provide the grower with optimal quality and quantity of light during the production cycle.

If you want to conduct your own experiments, Phytofy RL is an excellent research tool with wavelengths from UV-A to far red. For investigation of specific growth recipes, OSRAM offers research-as-a-service with professional staff applying fully controlled environments in order to provide you with the best growth choices for your crop.

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