NASA POSTDOCTORAL PROGRAM

Comparative Study of Lettuce and Radish Grown Under Red and Blue LEDs and White Fluorescent Lamps

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INTRODUCTION

Growing vegetable crops in space will be an essential part of sustaining astronauts during long-range missions. To drive photosynthesis, red and blue light-emitting diodes (LEDs) have attracted attention because of their efficiency, longevity, small size, and safety. In efforts to optimize crop yield, there is also recent interest in analyzing the subtle effects of additional wavelengths on plant growth. For instance, since plants often look purplish gray under red and blue LEDs, the addition of green light allows easy recognition of disease and the assessment of plant health status. However, it is important to know if wavelengths outside the traditional red and blue wavebands have a direct effect on enhancing or hindering the mechanisms involved in plant growth.

In this experiment, a comparative study was performed on two short cycle crops of red romaine lettuce (*Lactuca sativa* cv. 'Outredgeous') and radish (*Raphanus sativa* cv. 'Cherry Bomb'), which were grown under two light treatments. The first treatment being red (630 nm) and blue (450 nm) LEDs alone, while the second treatment consisted of daylight tri-phosphor fluorescent lamps (CCT~5000°K) at equal photosynthetic photon flux (PPF). The treatment effects were evaluated by measuring the fresh biomass produced, plant morphology and leaf dimensions, leaf chlorophyll content, and adenosine triphosphosphate (ATP) within plant leaf/storage root tissues.

LIGHT TREATMENTS

The RB treatment consisted of 50-W "UFO" AIBC fixtures with 8:1 red:blue ratio (Figure 1). The FL treatment utilized daylight T5 fluorescent tubes. Both treatments were placed in the same chamber with a non-reflective black separator between them to prevent light contamination. PPF was maintained at ~200 $\mu mol \cdot m^{-2} \cdot s^{-1}$ for both crops. The photoperiod was 18 h of active light, and 6 h of darkness.

The spectral distributions in Figure 1 reveal no evidence of light contamination between treatments. The RB LEDs exhibit narrow bands at ~450 and 630 nm, while the tri-phosphor FL treatment consists of multiple sharp bands extending throughout the UV, visible, and infrared spectral regions.

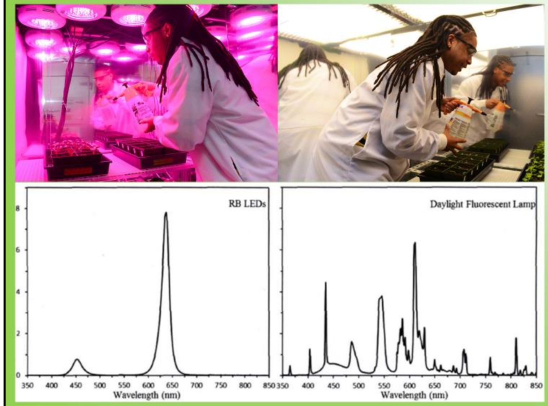

Figure 1. Light treatments and spectral distributions.

CULTURAL CONDITIONS

The lettuce and radish seeds were planted in 10 plastic pots (7 cm tall, 164 mL capacity) containing Fafard 2B potting mix (2 replications). A 1 inch layer of sifted arcillite (Turface proleague) was placed at the bottom of each pot to generate a perched water table accessible to plant roots. Four seeds were planted per pot and were thinned by removing 1 plant at 7,10, 17, and 25 days after planting (DAP).

Figure 2. Overhead views of planting arrangement.

As shown above in Figure 2 (right), the pots were arranged inside a 0.3 m^2 tray and were rearranged and rotated every other day to minimize edge and position effects within the chamber. The air temperature, relative humidity, and CO_2 levels were maintained constant at 23° C, 70%, and 1200 $\mu mol \cdot mol^{-1}$, respectively.

HARVEST RESULTS & DISCUSSION

Figure 3. Lettuce and Radish Harvest at 25 DAP.

In FL light, lettuce exhibited increased shoot dimensions, leaf size, and fresh biomass in comparison to the RB treatment (Table 1), but there were no significant differences in lettuce chlorophyll content. For radish, the RB treatment appeared to enhance the leaf/shoot growth while the additional wavelengths from the FL treatment triggered more biomass accumulation in the root storage, which provides the highest benefit for consumption. Although the total fresh mass was not significantly different under either treatment, the light quality affected how the biomass was distributed in the plant. The leaf chlorophyll content was also significantly higher under FL light, which may suggest improved nutrient content.

Table 1. Effects of light quality on shoot length, diameter, fresh mass, leaf area and chlorophyll content, n = 20, ± = SD.

Crop Type	Parameter	Light Treatment RB		FL		Significance Level
Lettuce	Shoot Length (mm)	150.6	± 3.145	178.0	± 2.956	***
	Shoot Diameter (mm)	261.7	± 5.843	314.1	± 4.061	***
	Total Fresh Mass (g)	13.09	± 0.579	16.58	± 0.919	**
	Leaf Area (cm^2)	343.5	± 14.90	462.7	± 18.23	***
	Chlorophyll ($g \cdot m^2$)	27.77	± 0.553	27.94	± 0.549	NS
Radish	Shoot Length (mm)	145.8	± 4.093	119.0	± 2.800	***
	Shoot Diameter (mm)	272.5	± 7.226	220.0	± 4.023	***
	Leaf Fresh Mass (g)	4.645	± 0.221	3.620	± 0.126	***
	Root Fresh Mass (g)	20.50	± 0.925	23.25	± 0.961	*
	Total Fresh Mass (g)	25.14	± 1.103	26.87	± 1.065	NS
	Leaf Area (cm^2)	130.0	± 7.453	103.6	± 4.314	**
	Chlorophyll ($g \cdot m^2$)	47.07	± 1.103	53.88	± 0.828	***

ATP ANALYSIS

ATP was analyzed to gain understanding of plant metabolism and energy expended for cellular processes such as protein synthesis and tissue growth in response to the light treatments. In the lettuce under RB light, there was a significant decrease in ATP going from 17-25 DAP as it approached the end of its cycle (Figure 4 top). Under FL light, there was no significant difference going from 17-25 DAP. The difference when comparing ATP levels between 2 treatments on the same DAP was not significant (Figure 4C and D).

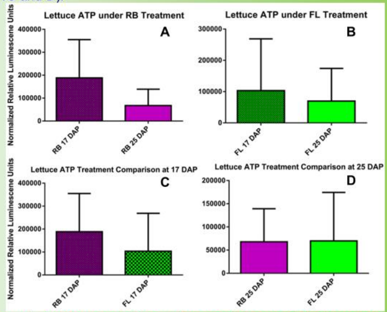

Figure 4. ATP from lettuce tissue 17 and 25 DAP, n=20, T=SD.

In radish, the leaf ATP was not significantly different under either treatment (Figure 5A and B). Although an increase in root ATP can be observed under RB (Figure 5C), the differences were not statistically different for either treatment going from 17-25 DAP.

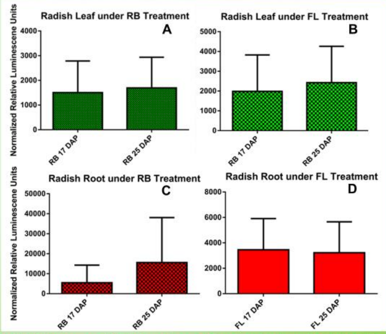

Figure 5. ATP from radish leaf/root tissue 17 and 25 DAP, n=20 T=SD.

CONCLUSIONS & NEXT STEPS

This study showed that broad spectrum fluorescent light triggered a response of improved morphology, and higher biomass accumulation for lettuce. However, the radish crops showed larger leaves under the red and blue LEDs, higher root fresh mass under fluorescent light, but no significant difference in total biomass between the 2 treatments. Although the ATP analysis revealed that leaf tissue of both crops exhibited similar responses to both treatments, it appears that ATP synthesis is likely more influenced by plant age. Ultimately, the effects of broad spectrum and narrow spectrum lighting on plant growth and ATP production are highly species-dependent. Our current experiments are evaluating the effects of blue, green, red, and far-red LEDs when supplemented with white LEDs.

ACKNOWLEDGMENTS

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