The Impact of LED Lighting on Carotenoid Concentrations in Hydroponically Grown Genovese Pesto Basil

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INTRODUCTION

The application of light emitting diode (LED) lighting systems in commercial greenhouse production is rapidly gaining popularity due to improved energy efficiency, increased spectral control, and reduction in manufacturing costs. Additional research is needed to determine the efficacy of LED lights in comparison to traditional lighting systems. Multiple studies have shown physiological and biochemical impacts of narrow-band blue/red wavelengths, specifically those involving secondary metabolism and the production of carotenoid and chlorophyll pigments (Colquhoun et al., 2013; Kopsell et al., 2013; Kopsell et al., 2014; Ouzounis et al., 2015; Kopsell et al., 2015a; Bantis et al., 2016). Increasing dietary levels of specific carotenoids and other antioxidants have been shown to help decrease the risk of certain cancers, combat the effects of aging, and support cardiovascular health (Pal et al., 2012; Kopsell et al., 2015b). The addition of supplemental LED lighting has the potential to manipulate secondary metabolism of high-value specialty herb crops and increase biosynthesis of key phytonutrients that are beneficial for human health.

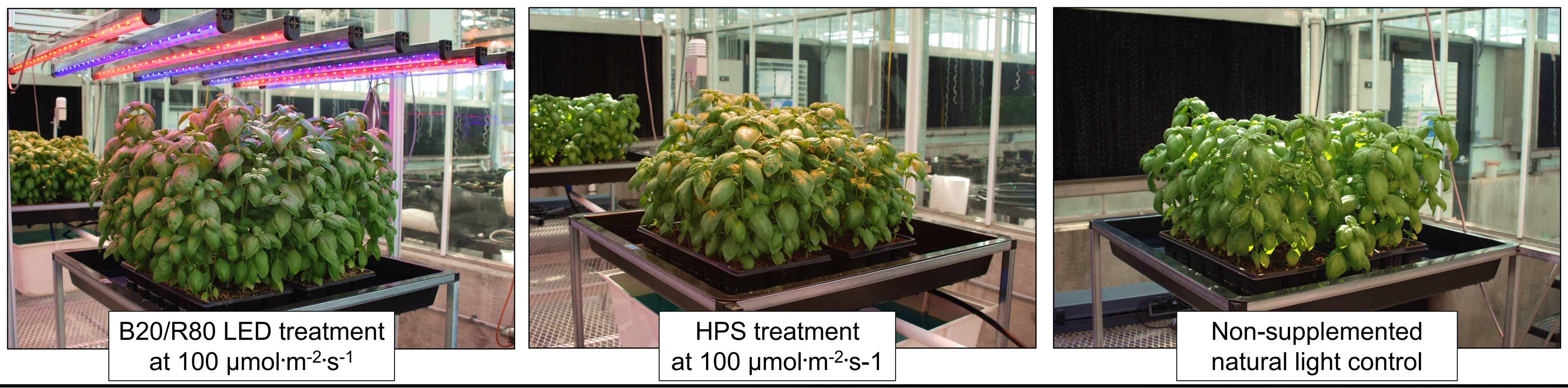
OBJECTIVES

Determine the impact of supplemental blue/red wavelengths on carotenoid and chlorophyll pigment bioaccumulation in 'Genovese' basil in comparison to traditional lighting systems.

MATERIALS AND METHODS

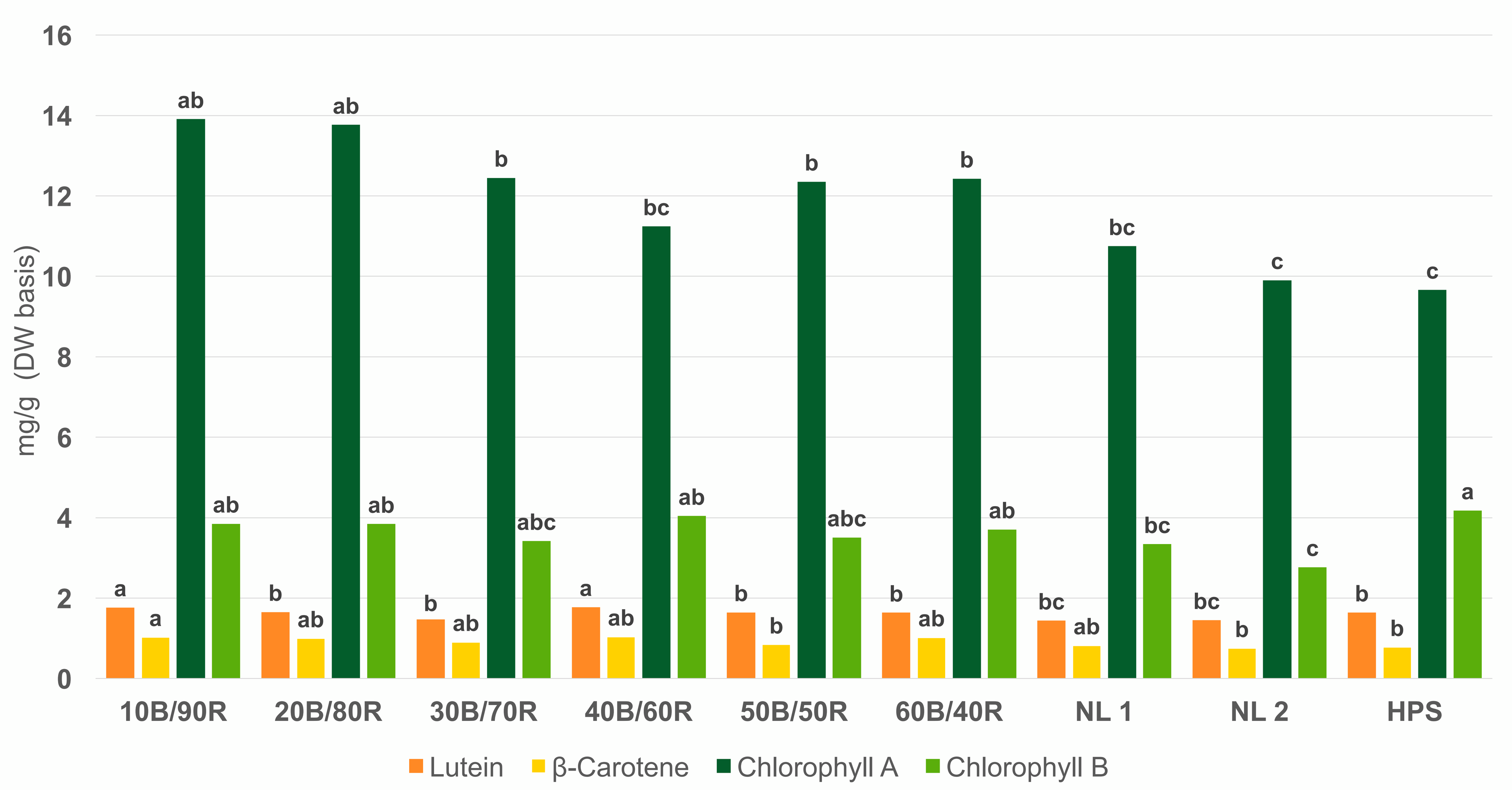
- **Crop:** 'Genovese' pesto basil (*Ocimum basilicum* L.) was specifically chosen because of its high value and demand among restaurants and professional chefs. Six experimental runs were performed from September 2015 to June 2016, and each crop was harvested 45 DAS.
- **Growing System:** Ebb and flow hydroponic system with a complete nutrient solution under normal greenhouse conditions.
- **Environmental Parameters:** 55% relative humidity; day temperature average 29.4°C; night temperature average 23.8°C; daily light integral (DLI) averaged 9.5 mol·m^{-2}·d^{-1} (ranged from 4 to 18 mol·m^{-2}·d^{-1}) during the growth period.
- **Light Treatments:** A total of nine lighting treatments were used, which included two non-supplemented natural light controls, one HPS, and six LEDs with progressive B/R ratios as: 10B/90R; 20B/80R; 30B/70R; 40B/60R; 50B/50R; and 60B/40R. Each supplemental lighting treatment provided 8.64 mol·m^{-2}·d^{-1} (100 µmols·m^{-2}·sec^{-1}, 24 h per day).
- **Experimental Design:** A Completely Randomized Design (CRD) was used for this experiment. Each of the lighting treatments contained six reps. Each rep consisted of two basil plants. Analysis of Variance (ANOVA) and Least Significant Difference (LSD) tests were performed using SAS statistical software (9.4, GLIMMIX).
- **HPLC Pigment Analysis:** Tissue samples were freeze-dried for 120 h and ground with liquid N. Pigments were extracted and then analyzed using an HPLC (Kopsell et al., 2013).

Figure 1. 'Genovese' pesto basil growing in greenhouse conditions under experimental lighting treatments.



RESULTS

Figure 2. LED treatment effects on carotenoid and chlorophyll pigment concentrations[1] per gram of fresh basil leaf tissue.



[1]Means with the same letter are not significantly different (LSD, α=0.05).

RESULTS, CONT.

Figure 3. LED treatment effects on xanthophyll cycle flux[1] ratios.

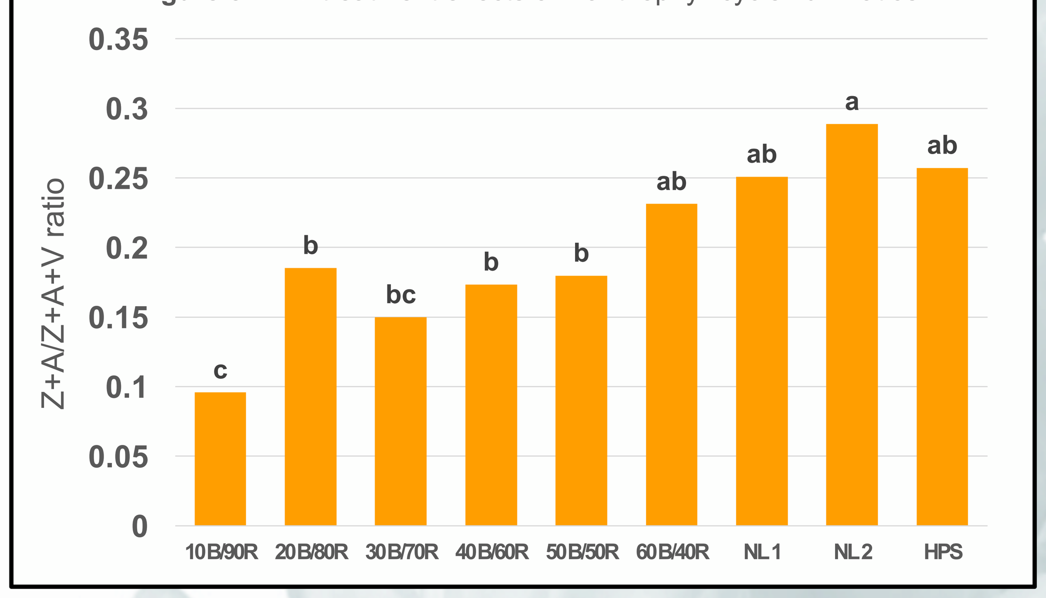
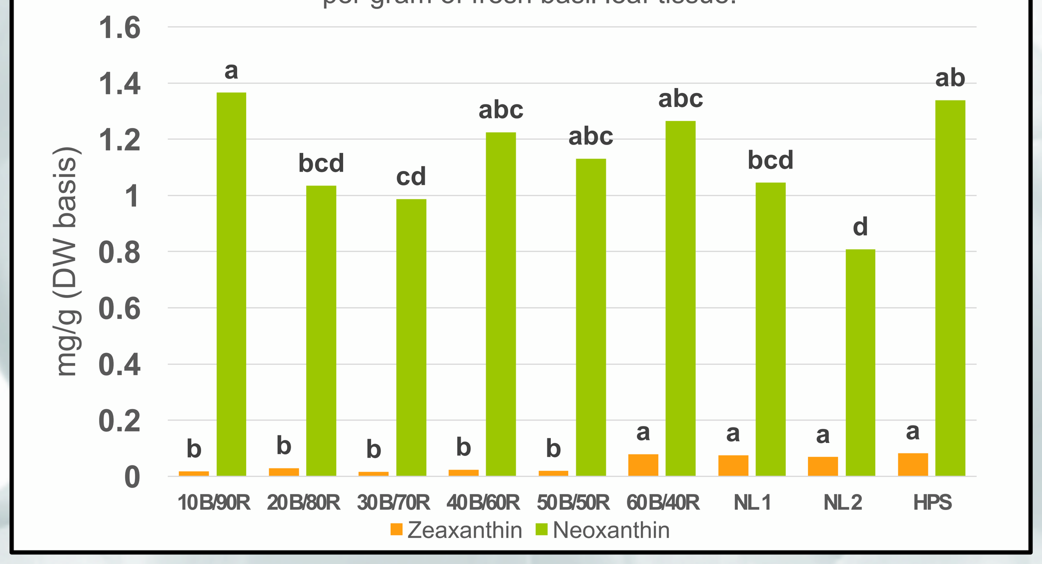


Figure 4. LED treatment effects on zeaxanthin and neoxanthin concentrations[1] per gram of fresh basil leaf tissue.



- All carotenoid and chlorophyll compounds evaluated in this study showed significant concentration variations in response to supplemental lighting treatments and non-supplemented controls ($P \leq 0.0001$).
- LED supplements generally resulted in higher pigment concentrations, with varying levels of significance.
- LED treatments and HPS supplements showed similar pigment concentrations for some of the compounds evaluated in this study, many of which were significant.
- The 10B/90R LED treatment resulted in higher concentrations among many of the pigments evaluated in this study (with the exception of zeaxanthin and chlorophyll b). The 40B/60R treatment resulted in the highest concentration of chlorophyll b.
- Interestingly, zeaxanthin concentrations were significantly lower in supplemented LED treatments versus controls.
- Increased ratios of Z+A/Z+A+V reflect changes to energy absorption and dissipation rates in response to variations in photosynthetic photon flux density (PPFD). All supplemental lighting treatments were provided at equal intensities, and this study demonstrates that xanthophyll cycle flux is influenced by spectral quality in addition to intensity.

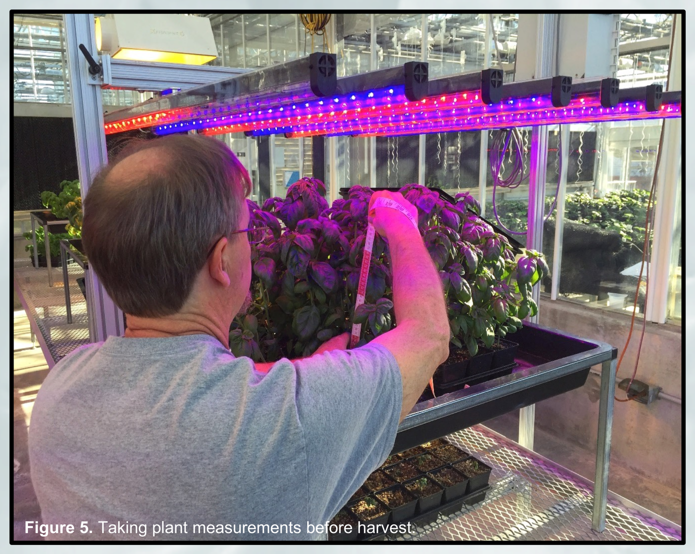


Figure 5. Taking plant measurements before harvest.

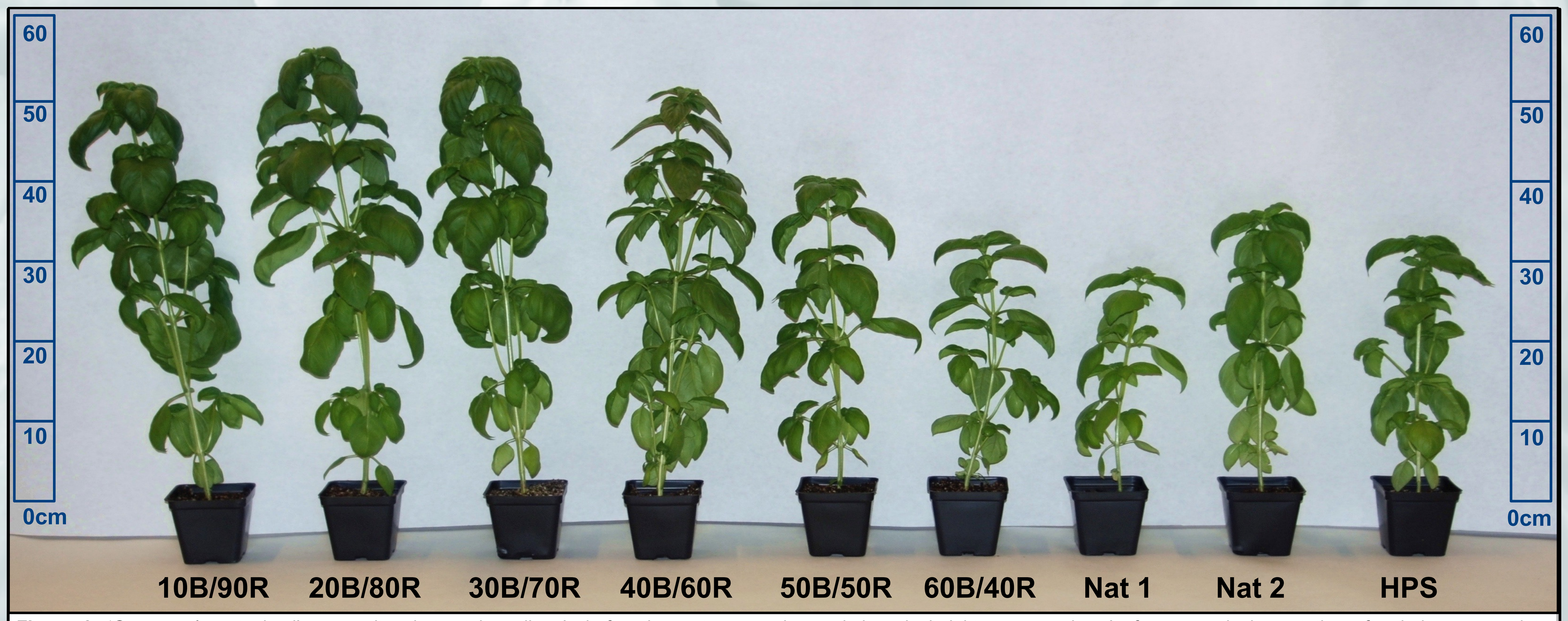


Figure 6. 'Genovese' pesto basil composite photo, taken directly before harvest, comparing variations in height, canopy size, leaf area, and pigmentation after being exposed to supplemental blue/red LED ratios, natural light controls, and broad-spectrum HPS supplemental lighting. All treatments (except controls) were provided 100 µmols·m^{-2}·sec^{-1} of supplemental light from transplant to harvest. NL controls were placed on opposite sides of the greenhouse bay to account for daily light integral (DLI) and spectral quality variations. Average NL control values were calculated from Nat 1 and Nat 2.

CONCLUSIONS

This study shows that the application of supplemental LED lighting systems have the ability to increase carotenoid and chlorophyll pigment concentrations in 'Genovese' basil. In addition, data demonstrates that spectral quality of supplemental lighting is an important factor in secondary metabolite synthesis. Further research should be conducted to establish the relationship between specific B/R wavelengths and bioaccumulation of beneficial phytonutrients. A thorough efficacy comparison between traditional lighting systems and LEDs is needed to demonstrate the impact of spectral quality (i.e. narrow-band wavelengths vs. broad spectrum supplements) on carotenoid and chlorophyll pigment biosynthesis. LEDs have the potential to improve antioxidant concentrations in many high-value specialty crops. Various herb varieties should also be evaluated to determine broad scale biochemical/physiological impacts of LED supplemental lighting on resource partitioning of secondary metabolism.

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