

Effects of different LED light wavelengths on the growth and antioxidant activity of red cabbage microgreens (*Brassica oleracea* L. var. *capitata* subvar. *rubra*)

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Abstract

This study aimed to determine the effects of LED lights with different wavelengths on the growth parameters, fresh weight, and total antioxidant content of red cabbage microgreens (*Brassica oleracea* L. var. *capitata* subvar. *rubra*) grown under controlled conditions. The experiment was conducted using a fully automated plant growth chamber, named “Confetti Cabin”, with four light treatments: red LED, blue LED, red+blue LED, and a natural light control group. The study was designed with a randomized plot design and three replications. The highest stem length was observed under red LED light (59.28 mm), the highest fresh weight under red+blue LED (90.70 g), and the highest antioxidant content under blue LED (0.99 EC50 µg/mL). The findings suggest that light spectrum selection can be optimized based on production targets in microgreen cultivation.

Keywords: Microgreens, Red Cabbage, LED Light, Antioxidant, Controlled Environment

INTRODUCTION

With the increasing population and urbanization in the world, demands for reliable and nutritional food are rapidly increasing. In this context, research about plant types suitable for short production durations, with high nutritional value and using sustainable production methods has gained importance. One of these types of products is microgreens, which comprise young seedlings of vegetable and aromatic plant seeds harvested in the germination process immediately before the formation of the first true leaves. These plants are attractive to both consumers and producers due to having high amounts of phytochemical, vitamin and antioxidant content in spite of low volume (Balık and Daşgan, 2025).

In the production of microgreens, environmental factors, especially light, are directly effective on plant development and metabolism. Light emitting diode (LED) technology offers an ideal lighting solution in controlled agricultural systems with the ability to disperse light with different wavelengths, low energy consumption, long life and compact structure. In the literature, LED lights with different wavelengths were shown to induce different effects on the morphological development of plants and production of secondary metabolites. Red (625-675 nm) and blue (425-475 nm) wavelengths, especially, are known to play important roles in plant growth due to being the spectrum intervals absorbed most by chlorophyll (Anderson et al., 1995; Bugbee, 2016).

Microgreens are characterized by higher nutritional concentrations compared to vegetables harvested in the standard growth stage (Xiao et al., 2012). The topic of the use of different wavelengths for successful microgreen cultivation environments requires planning by considering the plant type, growth stages and targeted outcomes. With different wavelengths, LED lights can produce specific wavelengths required to optimize photosynthesis and growth processes in plants (Bian et al., 2014). This may accelerate the plant growth process and increase yield. Additionally, LED lights have higher energy efficiency and lower cost compared to traditional lighting systems. LED lights offer the opportunity to leave more area for plant cultivation in enclosed spaces due to their more compact structure (Kozai et al., 2015).

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Different wavelengths may be used for different plant types and growth stages; this offers plant cultivators the opportunity to better control and optimize growing conditions (Massa et al., 2008). Identification and use of the correct wavelengths may improve plant health, reduce disease, and there may be an increase in nutritional value (Ouzounis et al., 2015). LED lights make it possible to grow plants independent of external weather conditions; thus, this may ensure the continuation of plant production throughout the year (Mitchell et al., 2015).

This study aimed to determine light strategies to increase production yield and optimize nutritional value by investigating the development and antioxidant content of *Brassica oleracea* L. var. capitata subvar. rubra (red cabbage) microgreens grown under LED light sources with different wavelengths.

MATERIALS AND METHODS

Research Environment and Plot Design

Trials were held in an automated microgreen production system called the “confetti cabin” located in Tekirdağ Namık Kemal University Technical Sciences Vocational School Air Conditioning Laboratory (Figure 1). Temperature (22 ± 2 °C), relative humidity (70%) and CO₂ level (max. 400 ppm) were kept constant with 16/8 hour light/dark photoperiods used.



Figure 1. Confetti cabin layout

Table 1 evaluates the four light implementations in the research, planned with three repeats according to the randomized parcels plot design.

Table 1. Microgreen cabin plot design

K1	K2	K3
L1-1	L1-2	L1-3
L2-1	L2-2	L2-3
L3-1	L3-2	L3-3

*K: Natural light (control); L1: Red LED (625-675 nm); L2: Blue LED (425-475 nm); L3: Red + Blue LED combination

Plant Material and Cultivation Conditions

Red cabbage (*Brassica oleracea* L. var. capitata subvar. rubra) seeds were used as plant material. Open-pollinated local standard varieties from the Bursa® seed company were used. The growth medium materials used for germination of seeds were white germination sponge (WGS). The sponges used are 3 mm thick polyethylene foam. Initial watering was performed and the germination process was monitored (Figure 2). The following conditions were also used for irrigation: pH: 7.82; electrical conductivity (EC): 603 $\mu\text{S}/\text{cm}$ (initial and later stages).



Figure 2. Microgreen cultivation tray

Measurement Parameters

Harvesting was performed with a sterile scissors from the root crown at the end of the 10th day. The parameters measured were:

- Stem length (mm): with a ruler between the root crown and the cotyledon
- Fresh weight (g): with a scale with 0.01 g sensitivity
- Total antioxidant content: with DPPH method in EC50 $\mu\text{g}/\text{mL}$

Total antioxidant capacity was calculated using the DPPH (1,1-Diphenyl-2-picrylhydrazyl radical; C₁₈H₁₂N₅O₆) radical scavenging activity, which uses a spectrophotometric approach. DPPH assay is a well-known method to estimate the capacity of radical scavenging of antioxidant compounds alone or in combination, as it is recognized as a simple, cheap, and fast method with very reproducible results (Silva et al., 2024)

Statistical Analysis

Data were analyzed with SPSS 22 program. After ANOVA variance analysis, the Tukey multiple comparison test was used to determine differences between the groups ($p < 0.05$).

RESULTS AND DISCUSSION

Microgreens cultivated in the microgreen cabinet were harvested 10 days after seeding. Harvesting was completed with a sharp sterile scissors at the plant root crown region of the microgreens (Figure 3). After harvesting was performed, microgreens were stored in a deep freezer at -20 ± 1 °C until analysis.

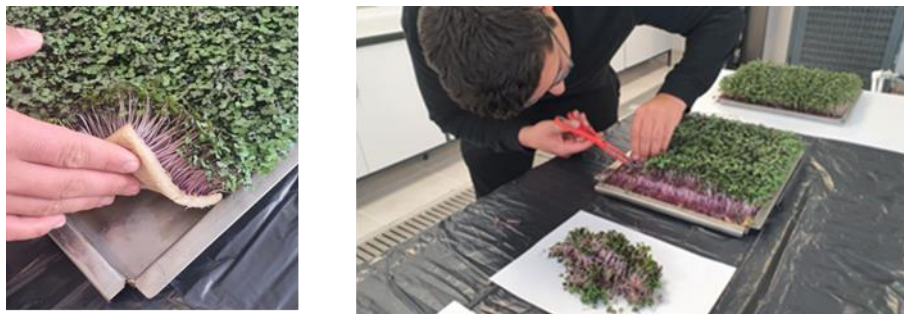


Figure 3. Microgreen Harvest

Within the scope of the research, the effects of LED light implementations with different wavelengths on the growth parameters and total antioxidant content of red cabbage microgreens were evaluated. The research results underwent ANOVA variance analysis and Tukey multiple comparison tests. The statistical analysis results for the research are given in Table 2. The findings revealed statistically significant differences ($p < 0.05$).

Table 2. Effect of different wavelength LED light on growth parameters and total antioxidant content of microgreens

Different LED light	wavelength	Stem length (mm)	Fresh weight (g)	Antioxidant (EC50 µg/mL)
Control group (K)		35.78±2.75 ^c	70.49±8.19 ^b	0.82±0.15 ^a
Red LED (L1)		59.28±4.28 ^a	58.10±8.11 ^{bc}	0.75±0.08 ^{ab}
Blue LED (L2)		40.60±7.07 ^{bc}	50.38±6.40 ^c	0.45±0.07 ^c
Red+Blue LED (L3)		52.44±2.56 ^{ab}	90.70±4.62 ^a	0.70±0.08 ^b

a, b, c(↓) show statistical differences between LED lights for plant types in the same column

Differences between rows shown with different letters are significant ($p < 0.05$)

When the table is investigated, the application of different LED light wavelengths significantly influenced the growth parameters and antioxidant activity of microgreens. Stem length was highest under Red LED (L1) treatment (59.28 ± 4.28 mm), indicating its strong effect on elongation compared to the control (35.78 ± 2.75 mm). Conversely, the Red + Blue LED (L3) combination resulted in the greatest fresh weight (90.70 ± 4.62 g), suggesting a synergistic effect on biomass accumulation. The Blue LED (L2) treatment exhibited the highest antioxidant activity, as reflected by the lowest EC50 value (0.45 ± 0.07 µg/mL), indicating enhanced bioactive compound synthesis under blue light exposure. This situation parallels the studies of Johkan et al. (2010), Brassica et al., (2023), Briggs et al., (2026), Narouei et al., (2024) and Ouzounis et al. (2015), which indicated that blue light stimulates the phenylpropanoid pathway, promoting the synthesis of phenolic compounds exhibiting antioxidant properties. The high activity observed in the Red+Blue (L3) combination proves that the synergy between the spectra plays an optimizing role in both growth and nutritional quality (Brazaityt'e et al., 2021; Pavlović et al., 2025).In light of statistical analyses, when the effects of different wavelength LED lights on the growth and antioxidant features of microgreens are evaluated, statistically significant differences were observed ($p < 0.05$). In terms of stem length, the highest value was observed for plants cultivated under red LED lights (L1). This situation may be explained by red light having photomorphogenetic effects encouraging plant growth. In terms of stem length, the production of the highest values under red LED light is associated with the photomorphogenetic effects of this light, which encourages cell expansion and elongation processes in plants (Smith, 1995). This result is consistent with previous studies emphasizing the dominant role played by red light in plant development.

The highest value in terms of fresh weight was obtained in plants cultivated under the red+blue LED combination (L3). This finding leads to consideration that the synergic effect of both wavelengths contributed to the increase in biomass. The blue LED implementation (L2) resulted in lower fresh weight values compared to the other groups. The highest value for fresh weight being obtained with the red+blue LED combination shows the synergic effect of these two wavelengths increased biomass production. Color combinations were stated to have positive impacts in terms of both leaf and stem development during growth in the literature (Bugbee, 2016; Viršilė et al., 2017).

The highest value in terms of antioxidant content was observed in the blue LED group (L2). Statistically significant differences were obtained for all parameters, with significant variability observed between the groups. In terms of antioxidant content, the highest value being obtained with the blue LED implementation indicates that blue light encourages synthesis of secondary metabolites like phenolic compounds (Havan et al., 2024). The study findings show that different LED wavelengths induced different effects on the development and functional compounds in red cabbage microgreens.

All these results reveal that the LED light spectrum does not just direct growth, but also functional quality parameters. In this way, determining light management strategies in line with production targets (yield increase, nutritional value increase, etc.) has great importance for controlled agricultural systems.

In conclusion, considering the effects of the light spectrum on growth and nutritional content in microgreen production, different LED implementations may be chosen linked to production targets. When biomass increase is priority, the red and blue LED combination (L3) may be recommended, while if an increase in antioxidant content is the target, the use of blue LED (L2) may be more advantageous.

CONCLUSION

In this study, the growth performance and antioxidant content obtained when red cabbage microgreens were cultivated in a controlled environment under LED lights with different wavelengths were evaluated. Red LED (L1) light positively impacted plant height by increasing stem length, while the red+blue LED (L3) combination supported increased biomass by providing the highest fresh weight values. Blue LED (L2) increased the functional value of the plants with the highest total antioxidant content. These findings reveal the need to specialize the selection of the light spectrum to be used in microgreen production according to production targets; for production prioritizing biomass yield, red+blue LED combinations are recommended, while for systems targeting functional compound production, blue LED dominant implementations are recommended.

Future studies may develop species-based optimized light prescriptions by trialing similar light protocols for different vegetable species, create more complex models to investigate the effect of variables like light intensity and photoperiod

duration, and evaluate commercial-scale applicability through economic analyses by calculating energy efficiency and return on investment durations.

Conflict of Interest

The authors declare no conflicts of interest.

Author Contribution

All authors contributed equally to the study design, data collection, analysis, and manuscript preparation.

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