Original Research Paper

Blue Light Exposure Duration Improves Antioxidant Capacity in Mung Bean Seedlings (*Vigna radiata* L.)

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Abstract: Antioxidant chemicals found in mung bean (*Vigna radiata* L.) sprouts may help prevent non-communicable diseases linked to oxidative stress; however, it is unknown how long exposure to blue light affects the build-up of these bioactive substances. This study aimed to evaluate the effect of different duration of blue LED light exposure on growth, antioxidant activity, and antioxidant-related compound in mung bean sprout. Three replications of a completely randomized design (CRD) were used. The Folin-Ciocalteu method was used to measure total phenolic content, iodometric titration was used to measure vitamin C, and the DPPH assay was used to measure antioxidant activity. According to the results, antioxidant activity increased significantly ($p<0.05$) under 24-hour exposure to blue light (30.34±0.61%) compared to darkness (26.40±0.39%). Additionally, tests made using the Folin-Ciocalteu technique and iodometric titration show an increasing tendency when exposed to blue light. Dry weight and hypocotyl length were not considerably impacted by light treatment. These results suggest that blue light duration is important for boosting antioxidant capacity without sacrificing development. This discovery offers a workable method for enhancing the functional quality of mung bean sprouts for controlled-environment agriculture systems and functional food development.

Keywords: Antioxidant; Blue light; Light duration; Mung bean sprout.

Introduction

Non-communicable diseases (NCDs), including cancer, stroke, and diabetes, are the leading causes of global mortality. According to the World Health Organization (WHO, 2023), unhealthy lifestyles such as smoking, a sedentary lifestyle, and a poor diet are major contributors to the increasing prevalence of NCDs. In Indonesia, national health data have also reported a significant rise in NCD cases (Kementrian Kesehatan Republik Indonesia, 2025). One of the major underlying factors in NCD development is oxidative stress caused by excessive free radicals, leading to cellular damage. Therefore, the consumption of antioxidant-rich foods has been widely recognized as an effective strategy to reduce the risk of NCDs (Nediani & Giovannelli, 2020; Chandimali et al., 2025).

Mung beans (*Vigna radiata* L.) sprouts are widely consumed in Southeast Asia (Sequeros et al., 2021) and are considered as valuable functional food due to their high nutritional value and bioactive compound content (Ebert, 2022; Karaman et al., 2024). Compared to dry seeds, sprouts contain higher levels of antioxidant compound, such as vitamin C and polyphenols, which contribute to health maintenance and the prevention of oxidative stress-related diseases (Siriparu et al., 2022; Chandimali et al., 2025). In Indonesia, mung bean sprouts are commonly consumed, with a reported weekly per capita consumption of 7.233g (Badan Pusat statistic, 2025), highlighting their importance in daily diets and their potential as dietary source of natural antioxidant.

Plant growth and the build-up of bioactive compounds are both regulated by light (Paradiso

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& Proietti, 2021; Wu et al., 2025). Prior research has demonstrated that certain light spectra, especially blue light, can increase antioxidant activity and secondary metabolite accumulation in a variety of sprout types, despite the fact that sprouts are typically grown in dark environments (Qian et al., 2016; Mastropasqua, 2020; Zao et al., 2024). Furthermore, it has been observed that the duration of light exposure affects the equilibrium between growth and the generation of active compounds (Lim et al., 2023). The function of blue light exposure time in controlling antioxidant accumulation in mung bean sprouts is still unknown, despite several investigations on light quality, pointing to a crucial research gap.

Therefore, this study aimed to evaluate the effect of blue light duration (12 hours and 24 hours) on growth, antioxidant activity, vitamin C, and total phenolic content of mung bean sprouts. This study is expected to provide insights into the role of light duration in regulating biochemical responses and to offer practical strategies for improving the nutritional quality of mung bean sprouts.

Materials and Method

Research location and duration

This study was conducted from May to September 2025 at the Biotechnology Laboratory, Faculty of Biotechnology, University of Surabaya, Indonesia.

Research Design

This study employed a Completely Randomized Design (CRD) consisting five groups of treatment with three replications. The CRD was selected due to the relatively homogenous environmental condition in the laboratories.

Population and sample

Commercial mung bean seeds (*Vigna radiata* L) purchased from local store were used in this study. A total 150 g pre-germinate seeds were used for each experimental unit and placed in plastic containers. The independent variable was light treatment (light quality and duration), while dependent variables included hypocotyl length, fresh weight, dry weight, antioxidant activity, vitamin C content, and total phenolic content. Controlled variables included seed weight, temperature, light intensity, and the distance between the light source and the sprouts.

The instruments used in this study included spectral analyzer (HPP330) to determine LED light spectra photosynthesis meter to measure a photosynthetic photon flux density (PPFD), a digital balance for biomass measurement, and a UV-Vis spectrophotometer for biochemical analysis. ImageJ software was used for morphological measurements. The material used included mung bean seeds, distilled water, DPPH reagent, iodine solution, starch solution, Folin-Ciocalteu reagent, sodium carbonate, and gallic acid.

The light sources used in this study were commercially available LEDs. Spectral analysis showed that the white LED had peak wavelengths at 449.2 and 551 nm, while the blue LED had a peak wavelength at 457.5 nm. The sprouts were placed 30 cm below the light source, and the PPFD was maintained at 50 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (Figure 1).

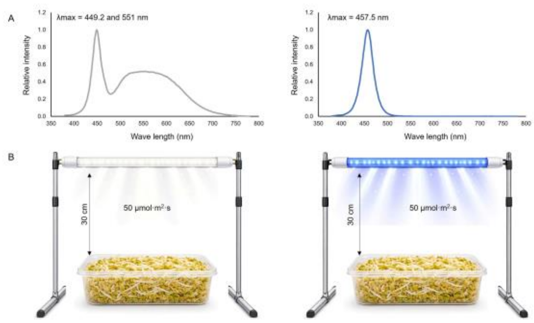

Figure 1. Lighting specifications and experimental setup. (A) Emission spectra for the white and blue LEDs. (B) Placement distance and light intensity measurements.

Research procedure

The seeds of mung beans were pre-germinated in water for twelve hours. Viable seeds were chosen, while floating seeds were thrown away. The following light treatments were applied to 150 g of seeds in plastic containers: 96 hours of darkness (96D), subsequently 84 hours of darkness followed by 12 hours of white light (84D12W), 72 hours of darkness followed by 24 hours of white light (72D24W), 84 hours of darkness followed by 12 hours of blue light (84D12B), and 72 hours of darkness followed by 24 hours of blue light (72D24B).

Ten sprouts from each replication were chosen at random for morphological examination using ImageJ software at the conclusion of the treatment period. A digital balance was used to determine the fresh weight. After that, the samples were dried for 12 hours at 50°C in an oven to determine their dry weight. Biochemical examination was performed on the dried materials. Using the DPPH radical scavenging method, antioxidant activity was assessed by measuring absorbance at 517 nm (Blois, 1958 with modification). The iodometric titration method was used to assess the amount of vitamin C (Georgescu et al., 2019), and the Folin-Ciocalteu method with absorbance measured at 765 nm was used to evaluate the total phenolic content (Liu et al., 2016).

Statistical Analysis

Data were analyzed using one-way analyses of variance (ANOVA) to evaluate the effect of treatments. When significant differences were observed ($p<0.05$), Duncan's multiple range test was used to compare differences among treatment means. For parameters where comparison with the control was primary interest, Dunnett's test was applied to compare each treatment with the control group (96D). Statistical analysis was performed using IBM SPSS Statistic version 27 software. The data of vitamin C and total phenolic were presented descriptively due to limited replication.

Result and discussion

The Influence of light treatment on the antioxidant activity, vitamin C levels, and total phenolic content

Table 1 shows how light treatment affected the mung bean sprouts' total phenolic content, vitamin C concentration, and antioxidant activity. When compared to the control, light therapy generally increased antioxidant activity (96D). Sprouts exposed to blue light for 24 hours had the maximum antioxidant activity (72D24B), whereas those subjected to constant darkness had the lowest value (96D). Dunnett's test showed that the 24-hour blue light treatment (72D24B) produced significantly higher antioxidant activity compared to the control, indicating that treatment effects were particularly noticeable when compared directly to the control group, even though ANOVA did not reveal significant differences among treatments. In addition, vitamin C and total phenolic content exhibit increasing trend under light condition with the highest content observed under 24-hour of blue light exposure.

Table 1. The effect of light treatment on antioxidant activity, ascorbic acid content, and total phenolic content of mung bean sprouts.

Group	DPPH inhibition (%)	Ascorbic acid ($mg \cdot g^{-1}$ D.W)†	Total phenolic ($mgEGA \cdot g^{-1}$ D.W)†
96D	26.40±0.39	3.17	5.10
84D12W	29.33±2.03	4.42	5.27
72D24W	29.88±1.20	4.83	5.50
84D12B	28.26±1.02	4.84	5.35
72D24B	30.34±0.61*	5.56	5.50

Data in the table represent mean values ±SD
For the DPPH assay n= 3
* Significant different ($p<0.05$) from the control as analyzed by Dunnett test. † Not statistically analyzed due to insufficient sample size.
DW = Dry weight

The current study's findings are in line with earlier research showing that blue light increases the build-up of secondary metabolites in sprouts and microgreens, such as phenolic compounds and ascorbic acid (Nam et al., 2018; Chutimanukul et al., 2022; Zhao et al., 2024: Mendes et al., 2025). Blue light has been shown to boost antioxidant activity in a number of sprout plants, including buckwheat (Nam, 2018), alfalfa (Sun et al., 2024), Toona sinensis (Ding and al., 2023), and Kaspa pea (Zhang et al., 2022). The activation of cryptochrome photoreceptors, which control the expression of genes involved in antioxidant production pathways, is linked to this impact (Wu, 2025). Therefore, by promoting the synthesis of bioactive molecules, extended exposure to blue light may increase antioxidant capacity.

However, the absence of significances in ANOVA suggests that the effect of light treatments was variable among replicates. Moreover, the lack of replication for Vitamin C and total phenolic measurements represents a limitation in this study. Future research with a larger sample size is necessary to confirm this trend. Nevertheless, the result indicate that blue light exposure duration has practical potential to improve the nutritional quality of mung bean sprout.

Growth Response of Seedlings to Light Treatments

The current study's findings are in line with earlier research showing that blue light increases the build-up of secondary metabolites in sprouts and microgreens, such as phenolic compounds and ascorbic acid (Nam et al., 2018; Chutimanukul et al., 2022; Zhao et al., 2024: Mendes et al., 2025). Blue light has been shown to boost antioxidant activity in a number of sprout plants, including buckwheat (Nam, 2018), alfalfa (Sun et al., 2024), Toona sinensis (Ding and al., 2023), and Kaspa pea (Zhang et al., 2022). The activation of cryptochrome photoreceptors, which control the expression of genes involved in antioxidant production pathways, is linked to this impact (Wu, 2025). Therefore, by promoting the synthesis of bioactive molecules, extended exposure to blue light may increase antioxidant capacity. Additionally, sprout grown under LED light exposure developed green cotyledon, whereas those grown under darkness remain yellow.

Figure 2. Sprout morphology post-treatment. Horizontal bar represents 1 cm.

Table 2. Effects of lighting treatments on hypocotyl length and biomass (fresh and dry weight) of mung bean (*Vigna radiata*) seedlings

Group	Hypocotyl length (cm)	Fresh weight (g)	Dry weight (g)
96D	3.43±0.77^{ns}	149.99±0.65^{a}	59.00±1.73^{ns}
84D12W	3.28±0.65	149.61±2.09^{a}	56.67±0.58
72D24W	3.68±0.70	148.44±0.75^{ab}	57.33±0.58
84D12B	3.38±0.54	146.98±0.72^{bc}	57.67±0.58
72D24B	3.14±0.52	145.57±0.81^{c}	58.33±4.04

Data in the table represent mean values±SD
For hypocotyl length, n = 30, for fresh and dry weight n = 3
Different letter in the table indicates significant different at p<0.05 analyzed by Duncan's multiple range test. Ns indicated not significantly different.

In contrast to earlier research suggesting that blue light prevents hypocotyl elongation, there were no appreciable variations in hypocotyl length (Ding et al., 2023; Lee et al., 2023; Falcinelli et al., 2024; Sun at al., 2024). This discrepancy may be attributed to relatively short duration of light exposure applied in this study. Blue light regulates plant morphology through cryptochrome-mediated signalling pathway that suppress auxin-related transcription factors involved in cell elongation (Ma et al., 2016). However, morphological responses to light are time-dependent (Carvalho and Folta, 2014); therefore, short-term exposure to blue light may not be sufficient to induce significant change in hypocotyl elongation of mung bean sprout in this study. This result is in line with other research demonstrating that sprouts only exhibit light-induced morphological responses following exposure for more than 36 hours (Lim et al., 2023). Light treatments had no discernible effect on dry weight, suggesting that brief exposure to light had little effect on biomass accumulation at this time. At this point, sprouts are more dependent on the cotyledons' stored reserves than on the reception of exogenous nutrients (Taiz et al., 2015). As a result, biomass accumulation is largely unaffected by light treatment.

On the other hand, the fresh weight of mung bean sprouts was considerably impacted by blue light. Water content has a significant impact on fresh weight, and in this experiment, no extra water was added during the treatment phase. Thus, sprout growth depended solely on water absorbed during the pre-germination. The observed reduction in fresh weight under blue light may be attributed to differences in physiological and metabolic activity. Under the dark condition, sprout metabolism in primarily directed toward cell expansion, whereas under blue light, metabolic activity shifts toward the synthesis of bioactive compounds, resulting in reduced cell expansion (Yin et al., 2026). As result, sprout grown in darkness exhibited higher fresh weight compared to those exposed to blue light, while sprouts exposed to blue light showed higher level of bioactive compounds. These findings indicate a trade-off between biomass accumulation and the production of functional compound. Therefore, the present study demonstrates that 24-hour blue light exposure influences both physiology and metabolism of mung bean sprout. These results suggest that the application of artificial lighting in sprout production should consider a balance between yield and nutritional quality.

Conclusion

The study demonstrates that blue light exposure affects both fresh weight and antioxidant capacity in mung bean sprout. Exposure to blue light for 24 hours significantly increased antioxidant activity, although it resulted in a slight reduction in fresh weight. These findings highlight the potential application of artificial light to enhance the bioactive compound content of mung bean sprouts while maintaining acceptable growth performance.

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