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The effects of melatonin and potassium fertilizer on fruit yield and quality of 'Haruhi' strawberry under two light conditions

Abstract. Strawberry (*Fragaria* × *ananassa*) 'Haruhi' is a subtropical plant that is being cultivated in Indonesia. High temperatures in tropical climates could decrease strawberry yield and fruit quality. The purpose of this study was to evaluate the effect of light, melatonin, potassium fertilizers, and their interactions on the yield and fruit quality of 'Haruhi' strawberry. This research was conducted from April to June 2024 at the Bale Tatanen, Faculty of Agriculture, Universitas Padjadjaran. A split-plot design was used, with lighting treatment as the main plot and melatonin and potassium fertilizer treatments as the subplot. Lighting treatments consisted of supplemental LED lighting and natural light (non-LED). Subplot treatments included control, 100 µM melatonin, 2 g L^{-1} potassium fertilizer, and their combination. The results showed that the combination of non-LED lighting with melatonin and potassium fertilizer produced the best fruit diameter and fruit weight. Under non-LED lighting, melatonin treatment resulted in the highest total soluble solids, while the control treatment produced the highest number of flowers. The interaction between LED lighting and melatonin resulted in the highest fruit number. Non-LED lighting alone also produced the best plant height, leaf number, and fruit length. Potassium fertilizer alone resulted in the highest leaf number, while the control treatment produced the highest plant height.

Keywords: *Fragaria* × *ananassa* · LED lighting · Natural light · Subtropical plant

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Introduction

Strawberry is a widely cultivated fruit crop worldwide, particularly *Fragaria × ananassa*, which originated from the hybridization between *Fragaria virginiana* from America and *Fragaria chiloensis* from Chile (Stewart & Folta, 2010). This fruit possesses high economic and nutritional value due to its high fiber, micronutrient, ascorbic acid, and phenolic compound content, which function as antioxidants (Battino et al., 2016). Although strawberry is native to subtropical regions, it is currently cultivated extensively, including in tropical countries such as Indonesia. Japan is recognized as one of the leading producers of high-quality strawberries known of its sweet taste and soft texture with higher commercial values (Yoshida, 2013). One of the recently developed cultivars in Japan is 'Haruhi', which is classified as a short-day plant. Based on domestic comparative tests conducted by its developer, Miyoshi & Co., Ltd., this cultivar is characterized by a moderately conical shape, a medium fruit size, and an average sweetness of 12.6 °Brix.

The growth, yield, and fruit quality of strawberries are influenced by environmental factors such as temperature, photoperiod, and light intensity (Khammayom et al., 2022). Strawberry plants grow optimally at temperatures 18–25°C in highland areas (Dinas Pertanian dan Pangan, 2020). Climatic variations can be minimized using greenhouse cultivation. Additionally, light is required for photosynthesis and plant growth. Supplementary light sources such as Light-Emitting Diode (LED) have been widely used due to energy efficiency, long lifespan, and ability to produce specific wavelengths (Nassawara et al., 2021). White LEDs are frequently used as the main lighting system since they provide a stable environment for vegetative growth (Smith et al., 2022). In addition to light quality, light intensity and photoperiod also affect plant development. Since different cultivars require different light requirements, it is essential to optimize the light environment to maximize fruit yield and quality (Zhang et al., 2026). LED lighting that is optimized for strawberries has been reported to increase photosynthetic pigment production, plant growth, and fruit weight (Roosta et al., 2024).

Cultivating strawberries in tropical regions is limited by high temperatures, which can reduce photosynthetic rate, yield, and fruit sugar content (Kadir et al., 2006). This condition could induce stomatal closure, restricting CO_2 uptake and decreasing photosynthetic activity up to 44% (Kadir et al., 2006). Melatonin treatment could be a potential way to address this problem, as previous reports suggest that melatonin helps in reducing chlorophyll degradation, increasing the photosynthetic rate, and improving chloroplast function under stress conditions (Zhang et al., 2013). A recent study by Manafi et al. (2022) showed that melatonin treatment at a concentration of 100 µM significantly decreased heat-induced damage symptoms and enhanced antioxidant defense response in strawberry plants. Therefore, melatonin at 100 µM was applied to improve plant adaptation under stress conditions.

High temperatures might not only decrease photosynthetic rates but also reduce the level of sugar accumulation in fruit and eventually decrease the fruit quality of strawberry. Nutrient availability, especially potassium, is essential for maintaining physiological functions, including sugar metabolism and the translocation of sugars from leaves to fruits (Ho et al., 2020). Valentinuzzi et al. (2018) showed that application of potassium-based foliar fertilizer significantly improved strawberry fruit quality, where Total Soluble Solids (TSS) increased by approximately 12% and Total Sweetness Index (TSI) increased by approximately 13%. Futhermore, Simorangkir (2015) reported that KNO_3 treatment at concentration of 2 g L^{-1} resulted in the highest TSS (25.99° Brix). Therefore, KNO_3 at 2 g L^{-1} was applied to improve fruit quality, especially fruit sweetness.

Previous studies have shown that melatonin treatment and potassium fertilizer treatment can increase strawberry yield and fruit quality (Manafi et al., 2020; Valentinuzzi et al., 2018). However, there are some limitations to how their combination works under various lighting conditions. This study was conducted to evaluate the effects of melatonin and potassium fertilizer on strawberry yield and fruit quality under different lighting conditions. Eventually, this will allow us to develop more efficient cultivation strategies for introduced strawberries, especially 'Haruhi' strawberry.

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Materials and Methods

Plant Material and Research Procedure. This experiment was conducted from April to June 2024 at Bale Tatanen, Faculty of Agriculture, Universitas Padjadjaran (718 m above sea level), Sumedang, Indonesia. The plant material used was 'Haruhi' strawberry seedlings obtained from Miyoshi Group, which were propagated in a nursery room before they were transferred to the greenhouse. Materials required for preparing growing media included cocopeat (45%), ash husk (45%), and peat moss (10%). Materials used for preparation of melatonin solution included 5 mg melatonin capsules, HCl solution, and distilled water. To prepare potassium fertilizer, materials used were KNO_3 fertilizer and water.

This experiment used a split-plot design with two-factor treatment and four replications. The lighting treatment factor served as the main plot, including natural light/non-LED (A_1) and supplemental LED lighting (A_2). The application of melatonin and potassium fertilizer treatment factor as the subplot, including control (B_1), 100 µM melatonin (B_2), 2 g L^{-1} potassium fertilizer (B_3), and a combination of 100 µM melatonin and 2 g L^{-1} potassium fertilizer (B_4). Therefore, eight treatment combinations were obtained: A_1B_1, A_1B_2, A_1B_3, A_1B_4, A_2B_1, A_2B_2, A_2B_3, and A_2B_4. Four replications have been used for all treatments, giving a total of 32 experimental units. Each experimental unit consists of two plants, giving a total number of 64 sample plants.

Measuring Plant Growth Performance Variables. The parameters observed in this study consisted of supplementary and primary observations. Supplementary observations included daily average temperature and Relative Humidity (RH), light intensity, and the incidence of pests and diseases, which were recorded daily from April to June 2024. Primary observations for plant growth included plant height (cm), number of leaves, number of flowers, number of fruits, and fruit set (%), which were measured at the end of the observation period (16 Weeks After Planting/ WAP). Primary observations for yield and fruit quality included fruit length (mm), fruit diameter (mm), fruit weight (g), and TSS (°Brix), which were measured on the first five fruits within a single inflorescence of each sample plant. All data were recorded in Microsoft Excel and then analyzed using analysis of variance (ANOVA) and Duncan's Multiple Range Test (DMRT) at a significance level of 0.05 through SmartStat XL V.3.6.5.3 add-in for Microsoft Excel.

Results and Discussion

Temperature and Relative Humidity (RH). The importance of temperature regulation was emphasized since temperature plays a key role in determining plant growth. The optimum temperature required for the growth of 'Haruhi' strawberries is between 18–25°C. According to Tang et al. (2020), suitable temperatures can also enhance fruit quality by increasing TSS levels. Observations showed that the average temperature in the greenhouse ranged from 24–31°C, which means above the optimal range for growth of 'Haruhi' strawberry plants and likely induced heat stress. According to Hastilestari (2015), heat stress can inhibit photosynthesis and reduce strawberry yield. In addition, Kadir et al. (2006) reported that high temperatures can reduce photosynthetic activity by up to 44%, lower yield, and decrease fruit sugar content.

Besides that, maintaining appropriate RH is also crucial for strawberry cultivation, as it affects the transpiration of leaves and fruits (Khammayom et al., 2022). Observations showed that the average daily RH during this experiment ranged from 58–81%. This range is wider than the optimal RH requirement for the 'Haruhi' strawberry plant, which ranged between 60–69% (Sobari et al., 2026). High humidity could increase the risk of fungal infections and soil-borne pathogens, eventually leading to reduced fruit quality and significant yield losses (Khammayom et al., 2022). Furthermore, low RH can increase transpiration and reduce water content of the strawberry fruit. According to Nunes (2014), water loss is one of the primary causes of strawberry quality deterioration, including reduced bioactive compound content.

Light Intensity. Daily observations of light intensity from April to June 2024 showed differences between LED and non-LED lighting treatments. During April, light intensity for the non-LED treatment ranged from 239.2 to 427.0 µmol/m²/s. These values were mostly within the optimal range for strawberry plant growth (250–450 µmol/m²/s) according to Guiamba et al. (2022). During May, light intensity under non-LED treatment varied between 193.4 and 529.0 µmol/m²/s, which means outside the optimal range for growth of strawberry plants. During June, non-LED treatment became more stable, with daily light intensity ranging from 250.2 to 323.1 µmol/m²/s, which means suitable for strawberry plant growth.

Under LED lighting, light intensity remained relatively stable throughout the observation period, ranging from 228.7 to 313.7 μmol/m²/s. Although light intensity was slightly lower on some days, the LED treatment generally provided suitable light for strawberry cultivation. During June, there is no requirement for supplemental artificial lighting since the non-LED treatment was suitable for strawberry plant growth. These results align with the findings of Sobari et al. (2026), who reported higher light intensity in non-LED treatment compared to the LED treatment. However, the LED treatment offered more relatively stable lighting conditions.

Pest and Disease. Observations found that strawberry plants have shown symptoms of leaf vein yellowing. According to Ferreira et al. (2023), these symptoms are generally caused due to nutrient imbalances. This may be an imbalance between potassium (K), magnesium (Mg), and calcium (Ca). High amount of potassium inhibits the uptake of Mg and Ca, leading to interveinal chlorosis, reduced chlorophyll content, and decreased plant vigor. Similar results were reported by Trejo-Téllez and Gómez-Merino (2014), the importance of balanced fertilization and soil pH management in preventing physiological disorders in strawberry plants. Therefore, proper nutrient management and regular soil pH monitoring are important measures to prevent this physiological disease.

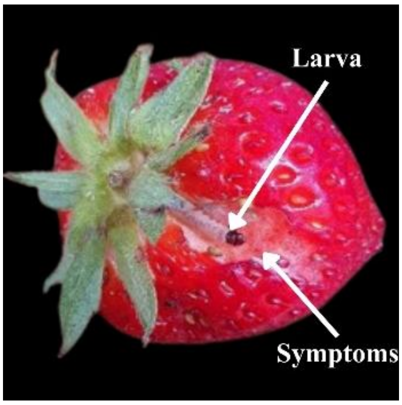

Figure 1. Symptoms and *Acleris* sp. larva infestation on 'Haruhi' strawberry fruit

In addition, several 'Haruhi' strawberry fruits were damaged by Acleris sp. Larva (Fig. 1), which produced holes and tunnel-like feeding scars on the fruit surface. The larva was identified based on their yellowish-white segmented body and reddish-brown head, consistent with descriptions from European Food Safety Authority (2019). Larva feeding reduced fruit quality and increased susceptibility to secondary pathogen infection. Pest control was carried out through routine monitoring and pruning of infested plant parts, which effectively limited infestation during the study.

Table 1. Main effects of lighting and the application of Melatonin and Potassium fertilizer on the height of 'Haruhi' strawberry plants at 16 weeks after planting

Treatment	Plant Height (cm)
Lighting	
Non-LED	23.49 a
LED	21.98 a
Melatonin and Potassium Fertilizer	
Control	24.63 a
Melatonin	22.75 a
Potassium Fertilizer	21.34 a
Melatonin + Potassium Fertilizer	22.22 a

Note: Means in the same column followed by the same letter are not significantly different according to DMRT at the 5% significance level.

Plant Height. Table 1 shows both the lighting treatment and melatonin and potassium fertilizer treatments had no significant effect on the plant height of 'Haruhi' strawberry at 16 WAP. However, strawberry plants under non-LED treatment show a slightly higher average plant height (23.49 cm) compared to those under LED lighting treatment (21.98 cm). These results showed that non-LED treatment was enough to provide light requirements for strawberry plant growth. The higher light intensity under non-LED treatment likely enhanced photosynthesis and stimulated plant growth. Similar findings were reported by Zou et al. (2025), who observed a 55% increase in strawberry plant height under sufficient lighting conditions. The control treatment shows the highest average plant height (24.63 cm), which means the greenhouse environment was already suitable for strawberry plant growth without additional treatments. Environmental factors such as temperature, RH, light, and nutrient availability likely supported optimal plant development (Mohmed et al., 2023). Furthermore, the higher plant height observed under non-LED treatment are attributed to the spectral characteristics of natural sunlight compared to LED lighting. Natural sunlight provides a full and balanced spectrum including enough proportion of far-red light that promotes steady and uniform stem elongation

(Zhen et al., 2022). Artificial lighting technologies replicate natural sunlight, which is considered the ideal light source due to its continuous and balanced full-spectrum wavelengths (spanning the 400–800 nm visible range) (Ling et al., 2026).

Number of Leaves. Table 2 shows the independent effect of lighting treatment on the number of leaves of 'Haruhi' strawberries at 16 WAP. Plants grown under non-LED treatment produced a higher average number of leaves (16.88 leaves) compared to those under LED treatment (15.53 leaves). This result shows that non-LED treatment provides the energy required for photosynthesis, which allows plants to produce organic matter and facilitate energy conversion during growth and development. Light also provides energy for metabolic processes such as cell division, cell differentiation, chlorophyll synthesis, tissue growth, and stomatal movement (Wu et al., 2025). Natural sunlight, with its continuous and balanced full-spectrum distribution, offers better light quality compared to LED lighting that more limited wavelengths. The optimal spectral balance provided by natural sunlight maximizes photosynthetic efficiency and supplies energy for plant growth, resulting in a higher number of leaves.

Observation shows that the potassium fertilizer treatment resulted in the highest number of leaves (17.31 leaves), although it was not significantly different from the control treatment (16.88 leaves). But these results show that potassium fertilizer treatment can still positively influence leaf growth. Potassium plays an important role in stomatal regulation, enzyme activation, and protein synthesis, which contribute to cell division and cell expansion, resulting optimal leaf growth (Hasibuan et al., 2024).

Table 2. Main effects of lighting and the application of Melatonin and Potassium fertilizer on the number of leaves of 'haruhi' strawberry at 16 weeks after planting

Treatment	Number of leaves
Lighting	
Non-LED	16.88 b
LED	15.53 a
Melatonin and Potassium Fertilizer	
Control	16.88 b
Melatonin	15.75 a
Potassium Fertilizer	17.31 b
Melatonin + Potassium Fertilizer	14.89 a

Note: Means in the same column followed by the same letter are not significantly different according to DMRT at the 5% significance level.

Number of Flowers. Table 3 shows a significant interaction effect between lighting treatment and the application of melatonin and potassium fertilizer treatment on the number of flowers per inflorescence 'Haruhi' strawberry plants. The highest number of flowers was observed in the control treatment under non-LED treatment, with an average of 20.66 flowers. This result shows that the environmental and physiological conditions were already suitable for flowering. Flower production in strawberry plants is affected by several factors, such as genotype, light intensity, and environmental conditions.

Table 3. Interaction effect of lighting, Melatonin, and Potassium fertilizer on the number of flowers per inflorescence of 'Haruhi' strawberry plants

Treatment	Number of Flowers			
	Control	Melatonin	Potassium Fertilizer	Melatonin + Potassium Fertilizer
Non-LED	20.66 b C	17.13 a B	17.00 b B	13.88 b A
LED	16.63 a B	17.50 a B	12.38 a A	12.50 a A

Note: Means followed by the same letter are not significantly different according to DMRT at the 5% significance level. Lowercase letters show comparisons between the two lighting treatments in the same treatment (vertical comparison), while uppercase letters show comparisons between treatments in the same lighting condition (horizontal comparison).

Table 4. Interaction effect of lighting, Melatonin, and Potassium fertilizer on the number of fruits per inflorescence of 'Haruhi' strawberry plants

Treatment	Number of Fruits			
	Control	Melatonin	Potassium Fertilizer	Melatonin + Potassium Fertilizer
Non-LED	15.35 a B	16.38 a B	16.13 b B	13.38 b A
LED	15.63 a B	16.88 a B	11.50 a A	11.88 a A

Note: Means followed by the same letter are not significantly different according to DMRT at the 5% significance level. Lowercase letters show comparisons between the two lighting treatments in the same treatment (vertical comparison), while uppercase letters show comparisons between treatments in the same lighting condition (horizontal comparison).

Table 5. Interaction effect of lighting, Melatonin, and Potassium fertilizer on the fruit set of 'Haruhi' strawberry plants

Treatment	Fruit Set (%)			
	Control	Melatonin	Potassium Fertilizer	Melatonin + Potassium Fertilizer
Non-LED	93.80 a A	95.75 a A	94.91 a A	96.52 a A
LED	94.00 a A	96.46 a A	92.84 a A	95.20 a A

Note: Means followed by the same letter are not significantly different according to DMRT at the 5% significance level. Lowercase letters show comparisons between the two lighting treatments in the same treatment (vertical comparison), while uppercase letters show comparisons between treatments in the same lighting condition (horizontal comparison).

Otherwise, the combined application of melatonin and potassium fertilizer treatment under both lighting conditions resulted in a lower number of flowers compared to the control. Although specific research on this interaction in strawberries remains limited, Chen et al. (2022) observed a similar mechanism in lettuce plants. This reduction could be a non-synergistic interaction between melatonin and potassium, which potentially interfered with the synthesis or transport of the florigen hormone, Flowering Locus T (FT), a key regulator of flowering initiation in plants.

Number of Fruits. Table 4 showed a significant interaction effect between lighting, melatonin, and potassium fertilizer treatments on the number of fruits per inflorescence of 'Haruhi' strawberry. The melatonin treatment under LED lighting produced the numerically highest number of fruits (16.88 fruits), but it was not significantly different from the control treatment (15.63 fruits). Similarly, under non-LED lighting, the melatonin treatment resulted in the numerically highest value (16.38 fruits), although it was not significantly different from the potassium fertilizer (16.13 fruits) and control (15.35 fruits) treatments.

Potassium fertilizer treatment resulted in a higher number of fruits under non-LED treatment but showed a significant decrease under LED treatment. This result shows that treatment effectiveness depends on environmental conditions, especially light intensity. Potassium is known to regulate carbohydrate metabolism and sugar synthesis, which support fruit development. Similar findings were reported by Hanif and Ashari (2014), who found that optimal KNO_3 application increased fruit number and fresh fruit weight. In addition, melatonin application has been reported to increase fruit production in strawberry plants compared to untreated controls (Ahmed & Abed, 2024).

Fruit Set. Table 5 showed no significant interaction effect between lighting, melatonin, and potassium fertilizer treatments on the fruit set percentage of 'Haruhi' strawberry. These results indicate that fruit set was not strongly influenced by light intensity or the application of melatonin and potassium fertilizer. Fruit set represents the proportion of flowers that successfully develop into fruits after pollination. Although a higher number of flowers may increase yield potential, not all flowers develop into fruits. The non-significant results suggest that fruit set was likely influenced more by other factors, particularly biotic pollination by insects such as bees. According to Rana et al. (2023), bee-assisted pollination significantly improved 87.16% strawberry fruit set compared to natural pollination.

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Table 6. Main effects of lighting and the application of Melatonin and Potassium fertilizer on the fruit length of 'Haruhi' strawberry

Treatment	Fruit Length (mm)
Lighting	
Non-LED	30.58 b
LED	30.01 a
Melatonin and Potassium Fertilizer	
Control	30.40 a
Melatonin	30.21 a
Potassium Fertilizer	29.69 a
Melatonin + Potassium Fertilizer	30.88 a

Note: Means followed by the same letter are not significantly different according to DMRT at the 5% significance level. Lowercase letters show comparisons between the two lighting treatments in the same treatment (vertical comparison), while uppercase letters show comparisons between treatments in the same lighting condition (horizontal comparison).

Fruit Length. Based on Table 6, the non-LED treatment produced significantly longer fruits compared to the LED treatment. This result may be related to the natural sunlight spectrum, which better matches the morphological requirements of strawberry plants for fruit growth and development. Specific light wavelengths can improve the efficiency of photosynthetic pigments, thereby supporting fruit development (Peng et al., 2020). Natural sunlight provides a full light spectrum, especially red and blue wavelengths that are important for photosynthesis and plant growth (Cetner et al., 2015). These conditions enhanced photosynthate accumulation and greater fruit length of strawberry.

Fruit Diameter. Based on Table 7, a significant interaction effect was observed between lighting treatment and the application of melatonin and potassium fertilizer on strawberry fruit diameter. The best results were obtained from the combination of melatonin and potassium fertilizer under non-LED lighting (28.40 mm), as well as the control (28.33 mm) and melatonin treatment (28.00 mm) under LED lighting. Previous studies by Zahedi et al. (2020) reported that melatonin application significantly increased strawberry fruit size. Besides that, potassium also plays an important role in assimilate transport to fruit and potassium deficiency may reduce fruit productivity and quality (Nakro et al., 2022). These findings suggest that the combination of melatonin, potassium fertilizer, and appropriate lighting conditions can effectively improve strawberry fruit size.

Fruit Weight. Based on Table 8, the combination of melatonin and potassium fertilizer under non-LED lighting produced the highest fruit weight (11.58 g) and differed significantly from the other treatments. The spectral composition of the light source plays an important role in photosynthetic efficiency since some wavelengths lead to the activation of photosynthetic pigments (Liu & Van Iersel, 2021). By optimizing the light spectrum, the photosynthetic rate could be maximized, resulting in greater photo-assimilate production (carbohydrates). Furthermore, the translocation of carbohydrates from source to sink during fruit development was also optimized, resulting in higher fruit weight (Naznin et al., 2016).

Table 7. Interaction effect of lighting, Melatonin, and Potassium fertilizer on the fruit diameter of 'Haruhi' strawberry

Treatment	Fruit Diameter (mm)			
	Control	Melatonin	Potassium Fertilizer	Melatonin + Potassium Fertilizer
Non-LED	26.68 a A	27.33 a AB	26.60 a A	28.40 b B
LED	28.33 b B	28.00 a B	26.90 a AB	26.23 a A

Note: Means followed by the same letter are not significantly different according to DMRT at the 5% significance level. Lowercase letters show comparisons between the two lighting treatments in the same treatment (vertical comparison), while uppercase letters show comparisons between treatments in the same lighting condition (horizontal comparison).

Table 8. Interaction effect of lighting, Melatonin, and Potassium fertilizer on the fruit weight of 'Haruhi' strawberry

Treatment	Fruit Weight (g)			
	Control	Melatonin	Potassium Fertilizer	Melatonin + Potassium Fertilizer
Non-LED	9.29 a A	9.85 a A	9.64 a A	11.58 b B
LED	10.47 b A	10.07 a A	9.35 a A	9.32 a A

Note: Means followed by the same letter are not significantly different according to DMRT at the 5% significance level. Lowercase letters show comparisons between the two lighting treatments in the same treatment (vertical comparison), while uppercase letters show comparisons between treatments in the same lighting condition (horizontal comparison).

Table 9. Interaction effect of lighting, Melatonin, and Potassium fertilizer treatments on the fruit weight of 'haruhi' strawberry

Treatment	Total Soluble Solid (°Brix)			
	Control	Melatonin	Potassium Fertilizer	Melatonin + Potassium Fertilizer
Non-LED	8.65 a A	10.03 b B	9.60 b B	9.58 b B
LED	8.69 a A	9.08 a A	8.73 a A	8.78 a A

Note: Means followed by the same letter are not significantly different according to DMRT at the 5% significance level. Lowercase letters show comparisons between the two lighting treatments in the same treatment (vertical comparison), while uppercase letters show comparisons between treatments in the same lighting condition (horizontal comparison).

Previous research has shown that melatonin positively impacts fruit yield by enhancing photosynthetic efficiency and the activity of growth-related enzymes. According to Okatan et al. (2022), melatonin treatment significantly increases strawberry yield and fruit weight, especially under greenhouse. Besides that, Schwarz et al. (2018) reported that potassium treatment increases strawberry fruit weight by supporting sugar transport, osmotic regulation, and protein synthesis. In addition, foliar application of potassium has proven more effective at increasing fruit weight when applied at optimal concentrations (Shkwr et al., 2022).

Total Soluble Solid. Based on Table 9, the application of melatonin, potassium fertilizer, and their combination significantly increased the TSS values of 'Haruhi' strawberry fruit under non-LED treatment compared to the control. Otherwise, no significant differences were observed under LED treatment, which shows that treatment effectiveness depends on the lighting conditions. These findings align with the results of Sobari et al. (2026), who reported that 'Haruhi' strawberries grown under non-LED treatment show higher TSS values compared to those under LED treatment. Under non-LED treatment, suitable natural light likely enhanced photosynthesis and promoted higher sugar accumulation within the 'Haruhi' strawberry fruit.

Melatonin has been reported to enhance photosynthetic activity by reducing chlorophyll degradation and improving chloroplast function (Zhang et al., 2013), which contributes to higher sugar accumulation in fruits. Potassium also plays an important role in carbohydrate synthesis and sugar transport from leaves to fruit. Previous studies have shown that potassium treatment increases sweetness level and overall fruit quality (Valentinuzzi et al., 2018). Therefore, the combination of optimal lighting, melatonin, and potassium fertilizer can synergistically enhance photosynthesis and sugar accumulation, resulting in higher fruit TSS values and improved fruit quality.

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Conclusion

Significant interactions were observed between lighting treatment and the application of melatonin and potassium fertilizer on the yield and fruit quality of 'Haruhi' strawberry. The combination of non-LED lighting with melatonin and potassium fertilizer produced the best fruit diameter (28.40 mm) and fruit weight (11.58 g). Under non-LED lighting, the interaction with melatonin resulted in the highest TSS (10.03 °Brix), while the interaction with the control treatment produced the highest number of flowers (20.66 flowers). Under LED lighting, the interaction with melatonin produced the numerically highest number of fruits (16.88 fruits), but it was not significantly different from the control treatment. Non-LED lighting was also the best independent treatment for plant height (23.49 cm), number of leaves (16.88 leaves), and fruit length (30.58 mm) of 'Haruhi' strawberry. For independent treatments, potassium fertilizer resulted in the numerically highest leaf number (17.31 leaves), although this was not significantly different from the control, whereas the control treatment produced the highest plant height (24.63 cm). For future research, it is recommended that experiments be conducted during two different seasons to evaluate the impact of varying environmental conditions. Supplemental LED lighting showed no significant results in this research because of high intensity of solar radiation in Indonesia remains relatively stable throughout the year. Therefore, the use of supplemental lighting is not recommended for future research, considering energy efficiency and operational costs.

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