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Growth Response, Physiology, Metabolomic, and Production of Micro-Tom Tomatoes to Additional Lighting with White and Purple Light-Emitting Diode

Wahyu Muhammad Yuha Lubis[A], Dhika Prita Hapsari*[B], Roedhy Poerwanto[B], Deden Derajat Matra[B]

[A] Graduate Program, Department of Agronomy and Horticulture, Bogor Agricultural University, Indonesia
[B] Department of Agronomy and Horticulture, Bogor Agricultural University, Indonesia

*Corresponding author; email: dhikaprita21@apps.ipb.ac.id

Abstract

Tomatoes are a widely produced and consumed fruit-vegetable belonging to the Solanaceae family. It contains minerals, vitamins, essential amino acids, sugars, and fiber. Micro-Tom is a wild-type cultivar from a cross between the Florida Basket and Ohio 4013-3 cultivars. Micro-Tom has two mutant types, the iaa9-3 and iaa9-5 mutants, which exhibit strong parthenocarpic properties. It is classified as a mutant tomato due to a mutation in the IAA9 gene, which belongs to the auxin/IAA (indole-3-acetic-acid) gene family and plays a role in suppressing the endogenous auxin signal transcription pathway. Using artificial light in cultivation techniques shortens the plant cycle and accelerates the juvenile phase. This study aimed to investigate the morphological, physiological, and production responses of Micro-Tom tomatoes to supplemental LED lighting. The research was conducted at the Leuwikopo experimental field of IPB University from March to November 2023. A completely randomized design was employed, with two factors (LED spectrum and Micro-Tom genotyping) and nine replicates. The study also examined the potential benefits of combining polychromatic and monochromatic light-emitting diodes (LEDs). The response of Micro-Tom tomatoes to artificial lighting with purple and white LEDs did not show significant differences in growth and production parameters. However, significant differences were observed between the tomato types, specifically between the Wild-type and the iaa9-3 mutant. No significant differences were found in LED treatment or Micro-Tom genotype for physiological parameters such as chlorophyll content and glucose-fructose levels. Regarding fruit quality, no significant differences were observed for parameters such as total soluble solids (TSS, Brix) to total titratable acidity (TTA, acidity), glucose and fructose, and malic acid. The LC-MS/MS analysis of leaves exposed to purple LED light revealed a profile dominated by secondary metabolites from the fatty acid compound group, suggesting the potential benefits of this lighting combination. In conclusion, using LED lights can accelerate the plant life cycle and shorten the juvenile phase, as evidenced by the first flower emergence, which occurred 20 days after transplanting (DAT) in the wild-type genotype and 16 DAT in the mutant genotype.

Keywords: artificial light, fatty acids, fruit quality, plant cycle, secondary metabolites

Introduction

Tomato (*Solanum lycopersicum* L.) is a widely favored annual horticultural product, highly commercialized due to its significant economic value (Lestari et al., 2020). This fruit contains essential antioxidants such as lycopene, ascorbic acid, and phenolic compounds, which help prevent chronic diseases, including coronary heart disease. Additionally, tomatoes are low in fat and calories, cholesterol-free, and a source of natural fiber, vitamins, carotenoids, and phenols (Anas et al., 2022; Domínguez et al., 2020). Micro-Tom tomatoes (*Solanum lycopersicum* cv. Micro-Tom) are small model plants with a short life cycle, making them a valuable genetic resource for research aimed at improving tomato quality (Wahyudi et al., 2021).

Morphogenesis, the process of growth and cell differentiation in organisms, plays a crucial role in plant development. In plants, morphogenesis begins with the formation of the plant's morphological characteristics, eventually resulting in a complete individual. Both genetics and environmental factors influence this growth and differentiation process (Saputri et al., 2019). Light intensity and quality are key to photosynthesis and plant photomorphogenesis (Nacheva et al., 2021). Several studies have demonstrated a response to light intensity, such as

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increased chlorophyll accumulation in kiwi plants under higher light intensities (Xiaoying et al., 2022).

LED lights offer several advantages in plant cultivation, including energy efficiency, high photosynthetic efficiency, small size, low heat output, and adjustable spectra tailored to the specific growth needs of plants (Matysiak et al., 2021). Plant growth encompasses various physiological aspects, including germination, leaf expansion, stem elongation, flower formation, and organ differentiation, all of which are influenced by light. Artificial light can stimulate plant growth and development, accelerating the juvenile phase (Yamazaki et al., 2018). For example, white light effectively induces new leaf formation and increases the photosynthetic pigment content in raspberry plantlets (Nacheva et al., 2021).

Artificial light is known to shorten the life cycle of annual plants, such as peas and canola (Ghosh et al., 2018). Light-emitting diodes (LEDs) have been shown to modify plant metabolic pathways, enhance photosynthate accumulation in sink areas, and optimize carbohydrate translocation without interference from other sink competitors, ultimately improving fruit yield and quality (Wargent, 2016).

In recent years, multi-omics approaches, including genomics, transcriptomics, proteomics, metabolomics, ionomics, and phenomics, have been successfully applied in plant development systems. This study employs metabolomics, an approach that detects the composition of metabolites in plants, to understand the mechanisms of adaptation, acclimatization, and plant defense against stress (Patel et al., 2021). Liquid Chromatography-Mass Spectrometry (LC-MS) and Gas Chromatography-Mass Spectrometry (GC-MS) are two commonly used methods in metabolomics, both of which have proven effective in analyzing metabolite compounds in plants, such as guava (Tousif et al., 2022).

This study aims to investigate the response of Micro-Tom tomato plants to LED light treatment, utilizing LEDs as both a substitute for sunlight and supplemental lighting. The hypothesis is that variations in LED treatment and Micro-Tom genotype will result in significant differences in plant responses.

Materials and Methods

The experiment was conducted from March to November 2023 under a screen house at the Leuwikopo Experimental Station, Department of Agronomy and Horticulture, IPB, Dramaga, Bogor, Indonesia (Latitude: -6.564441, Longitude: 106.724762, 250 m above sea level). Physiological and post-harvest observations were conducted in the Integrated Laboratory Seed Center, Department of Agronomy and Horticulture, IPB.

The experiment employed a completely randomized design (CRD) with two factors and nine replications. The first factor was a polychromatic LEDs (Fultrum Grow Light, 120 cm, T8 LED Tube) spectrum consisting of two levels: purple LED (combination of blue and red spectrum, red dominant, PPFD value of each light 86.09 $\mu mol.m^{-2}.s^{-1}$) and white LED (combination of all spectrums, blue dominant, PPFD value of each light 50.15 $\mu mol.m^{-2}.s^{-1}$), each level consisting four LED lights. The second factor was the genotype of the Micro-Tom tomato, which consisted of two levels: wild-type and iaa9-3 mutant.

Experimental Procedures

The plant material used was Micro-Tom tomato seeds obtained from the University of Tsukuba, Japan. These seeds germinated for two weeks in a seed tray before being transplanted into polybags. Growing media consists of a mixture of soil and rice husk charcoal in a 1:1 ratio. The seeds are sown at a rate of 1 seed per tray hole at a depth of 1 cm. Seedlings are transplanted 14 days after sowing (DAS) with the criteria of being taller than 2 cm, having four perfect leaves, an upright stem, and disease-free. The seedlings are transplanted into 15 cm diameter polybags using the same media used during sowing. Subsequently, the plant material was placed in a screen house equipped with purple and white LED racks. LED light applications were administered according to the treatments with a 21-hour lighting period. The quantity of LED light was measured using a Licor LI-1500 light meter with a quantum sensor to obtain Photosynthetic Photon Flux Density (PPFD) values. Measurements were initiated from 5 AM to 7 AM GMT +7 at two-hour intervals. Plants were irrigated daily with a volume of 120 mL per plant. Fertilization was performed weekly through fertigation using NPK Growmore 20-20-20 (1 $g.L^{-1}$) via the growing media. Pest control was managed with two types of insecticides: Decis 25 EC (active ingredient deltamethrin) at a dose of 1 $mL.L^{-1}$ and Curacron 500 EC (active ingredient profenofos) at 1 $mL.L^{-1}$.

Growing Environment

The temperature and relative humidity inside the screen house were measured using an Elitech Data Logger RC-5 digital thermometer for 14 weeks during the LED application. Photosynthetic Photon Flux Density (PPFD) values of white and purple LEDs were measured once at the beginning of the application, from 5 AM to 7 PM.

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Plant Growth and Production Measurement

Observations of vegetative growth were conducted weekly, from 0 to 5 weeks after application (WAA), until the maximum vegetative stage was reached. Parameters measured included plant height and canopy diameter. Additionally, generative growth was monitored by recording the time of flowering, the number of flowers, and production, which involved counting the number of fruits and measuring their weight.

Physiological Measurement

Chlorophyll content was measured using the Warren method (2008) at 6, 10, and 14 WAA. A 0.56 cm² leaf sample was homogenized in a mortar with 2 mL of absolute methanol. The mixture was transferred to a 2 mL microtube and centrifuged at 16,940 RCF for 2 minutes. The supernatant was transferred to a new microtube and then washed again with 1 mL of fresh methanol before centrifugation. The remaining supernatant was combined with the previous supernatant, and 200 µL of the solution was transferred to a 96-well flat-bottom polystyrene plate. Absorbance was measured using a Multiskan Sky Microplate Spectrophotometer at wavelengths of 652 nm and 665 nm.

The glucose and fructose content in the leaves was tested at 6, 10, and 14 weeks after anthesis (WAA), following the method by Lanoue et al. (2019). A 0.56 cm² leaf sample was transferred to a 2 mL microtube and boiled in 1 mL of 80% ethanol in a water bath until the ethanol had evaporated, repeating this process twice. The sample was then dried at 50°C for 3 hours. The ethanol-soluble fraction was mixed with distilled water and 99% chloroform (1000µL:500µL, v/v) and centrifuged at 2200 RCF for 3 minutes. The supernatant was analyzed using the D-Fructose/D-Glucose Assay Kit (Megazyme K-FRGLQR), and absorbance at 340 nm was measured using the Multiskan Sky Microplate Spectrophotometer.

Fruit quality was tested by measuring the Total Soluble Solids (TSS, % Brix) and Total Titratable Acidity (TTA, % Acidity) values using the ATAGO PAL-BX/ACID1 (Pocket Brix-Acidity Meter Master Kit). Additionally, glucose-fructose content in the fruit was measured using the D-Fructose/D-Glucose Assay Kit (Megazyme K-FRGLQR), and malic acid levels were determined using the L-Malic Acid Assay Kit (Megazyme K-LMALQR).

Secondary Metabolite Profiling

Leaf samples from Wild-type and iaa9-3 under purple LED treatment were collected at 10 WAA as a composite from nine replications. The samples were ground using liquid nitrogen until they were powdered. One gram of the leaf powder was dissolved in 1 mL of 70% methanol and then sonicated at 50 kHz for 30 minutes at 28°C (Song et al., 2013). A 2 µL extract was injected into the UHPLC-Q-Orbitrap HRMS machine. Metabolites were separated using the method described by Tala et al. (2013), with an HPLC converter used for the mobile phase in LC-MS/MS. The optimal mobile phase consisted of water (A) and acetonitrile (B), containing 0.1% formic acid. The elution was performed with 5% acetonitrile for the first 5 minutes, followed by a gradient of 5-30% acetonitrile over the next 15 minutes. The column used was Accucore™ 100 x 2.1 mm x 2.6 µm, with a phenyl stationary phase. The injection volume was 0.2 µL, with a flow rate of 0.2 mL/min and a temperature of 35°C.

Data Analysis

Data were analyzed using analysis of variance (ANOVA) at a 5% significance level. Variables showing significant effects were further analyzed using Duncan's Multiple Range Test (DMRT) at a 5% significance level. Data processing was conducted using SAS System for Windows 9.0. LC-MS/MS output data were analyzed using Compound Discover 3.1 to identify the names and classes of compounds. Compound identification was confirmed through online databases PubChem (https://pubchem.ncbi.nlm.nih.gov/), ChemSpider (https://chemspider.com), and IMPPAT (https://cb.imsc.res.in/imppat). The process for determining the compound class involved simplifying the compound name using databases PubChem or ChemSpider, followed by class identification using the IMPPAT database.

Results and Discussion

Temperature and Relative Humidity

Based on the measurement and recording of air temperature over 14 weeks (Figure 1), the average temperature inside the screen house was 28.33°C, with a minimum temperature of 20.1°C and a maximum temperature of 42.3°C. Air temperature is a crucial environmental factor that influences plant metabolic activities, including photosynthesis, enzymatic reactions, and carbohydrate synthesis (Seydel et al., 2022). The white LED treatment resulted in an average PPFD value (Figure 2) of 123.15 µmol.m².s⁻¹, which was not significantly different from the purple LED treatment at 122.01 µmol.m².s⁻¹. Polychromatic LEDs have varying Red-

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Green-Blue (RGB) ratios, with blue light having a shorter wavelength than red light. The shorter the wavelength, the higher the photon energy produced (Zulviana et al., 2020). Higher-intensity blue light has been shown to promote the synthesis of chlorophyll a, b, and carotenoids during the early growth stages of spinach plants (Zou et al., 2020).

Environmental factors crucial for plant growth and development include air humidity and temperature. Air humidity regulates the transpiration rate, which in turn impacts plants' ability to absorb nutrients and water. Environmental temperature influences plant physiological and metabolic processes, including photosynthesis, flowering, fruit-set, and other enzymatic reactions (Adrian, 2022). Global climate change leads to an increase in temperature, and high-temperature conditions can cause changes in morphology, physiology, and biochemistry, resulting in reduced photosynthetic activity and decreased plant growth and productivity (Nievola et al., 2017).

Plant Growth and Production Measurement

The vegetative growth of plants, as indicated by plant height (Figure 3a) and canopy diameter (Figure 3b), did not show significant differences among the LED treatments. However, differences were observed in the genotypes of Micro-Tom tomatoes (Wild-type and iaa9-3) at 3-4 weeks after application (WAA). No significant differences were observed among LED treatments in generative parameters, such as flowering time (Figure 4a) and the number of flowers (Figure 4b). However, significant differences were observed between the two Micro-Tom tomato genotypes. Regarding production parameters, including the number (Figure 5a) and weight (Figure 5b) of fruits, no significant differences were noted.

The predominance of red light plays a key role in promoting the development of vegetative plant organs, mainly shoot organs (Cioc et al., 2022). Red LED light has been shown to increase plant height and stem diameter in Ramie plants (Boehmeria nivea) by enhancing photosynthesis (Rehman et al., 2020). Additionally, a higher proportion of blue light has been observed to increase the number of leaves in plants such as basil, spinach, and bell peppers (Naznin et al., 2019).

The fastest flowering time was observed in the iaa9-3 genotype, although most plants were in the wild-type

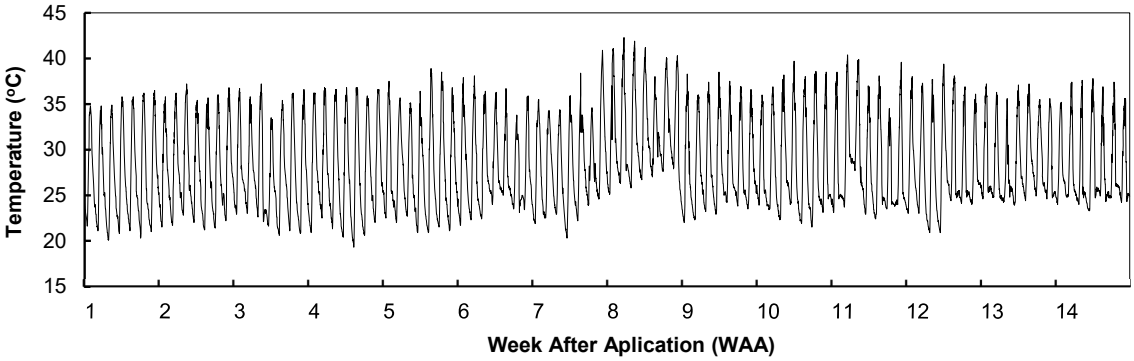

Figure 1. Daily temperatures in the screen house at 1 to 14 weeks after LED treatments 14 WAA

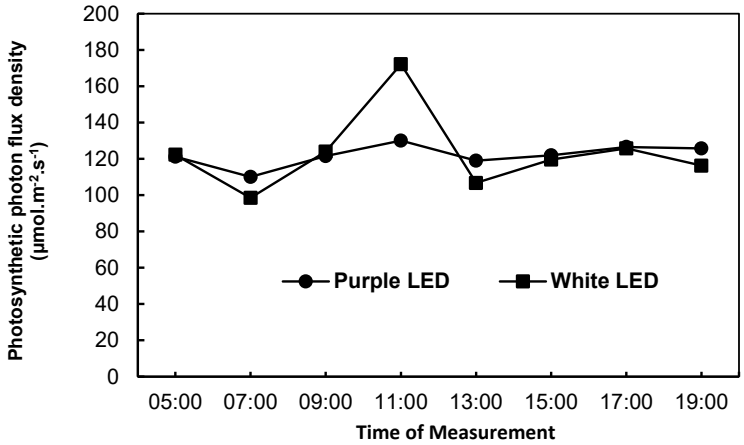

Figure 2. Photosynthetic photon flux density (PPF) values in the first week of LED application, showing changes in PPFD values on LED lights influenced by sunlight that passes through the screen house.

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genotype. The purple and white LED treatments did not show a significant difference. The number and weight of fruit did not show significant differences between LED treatments and genotypes. LED is applied to induce flowering (Magar et al., 2018). The study by Bowman and Albrecht (2021) found that LED artificial light during the seedling phase of citrus enhanced growth, particularly in accelerating shoot initiation.

Leaf Chlorophyll Content Analysis

Chlorophyll b content (Figure 6b) showed a decreasing trend from 6 to 14 MSA. Overall, the white LED treatment produced higher chlorophyll a and b contents compared to purple LEDs. However, this difference was not significant at 6 and 10 MSA. At 14 MSA, the chlorophyll a and b content in the iaa9-3 genotype under purple LED treatment increased again. Chlorophyll content tends to decrease as plants transition from the generative phase to the aging phase (Hendriyani et al., 2018). In Adrian's (2022) study on RB (red-blue) LED lighting in strawberries, no significant difference in chlorophyll content was observed. However, other studies found that blue light resulted in lower chlorophyll accumulation than red light in strawberry and cucumber plants (Choi et al., 2015; Nadalini et al., 2017). Additionally, combined light spectra led to 2.2 times higher chlorophyll content than plants exposed to monochromatic light (Pundir et al., 2020).

Glucose and Fructose Content Analysis

Leaf glucose content at 6, 10, and 14 weeks after LED application (WAA) (Figure 7a) increased. At 6 MSA, significant differences in glucose content were observed between the Micro-Tom tomato genotypes, and at 14 MSA, significant differences were found between the LED treatments. The fructose content in the leaves (Figure 7b) also increased from 6 to 10 WAA, but no significant differences were observed in either the LED treatment or the Micro-Tom tomato genotype. Glucose and fructose are photosynthates produced during the process of photosynthesis in plants. An increased red-to-blue light ratio has been shown to enhance total soluble sugar content in the leaves and improve stomatal conductance, although

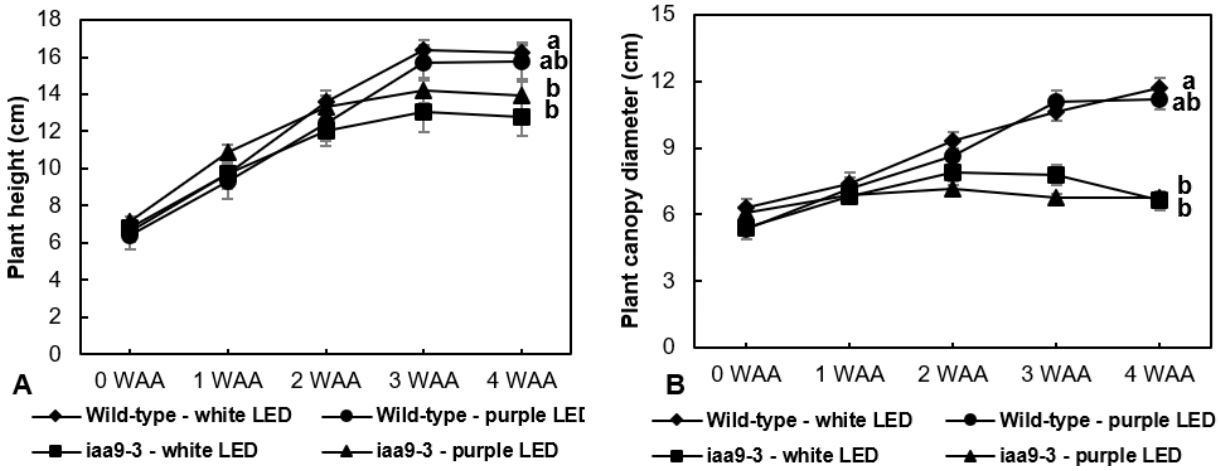

Figure 3. Graph of plant height against LED treatment for four weeks of application (a), graph of plant canopy diameter against LED treatment for four weeks of application (b).

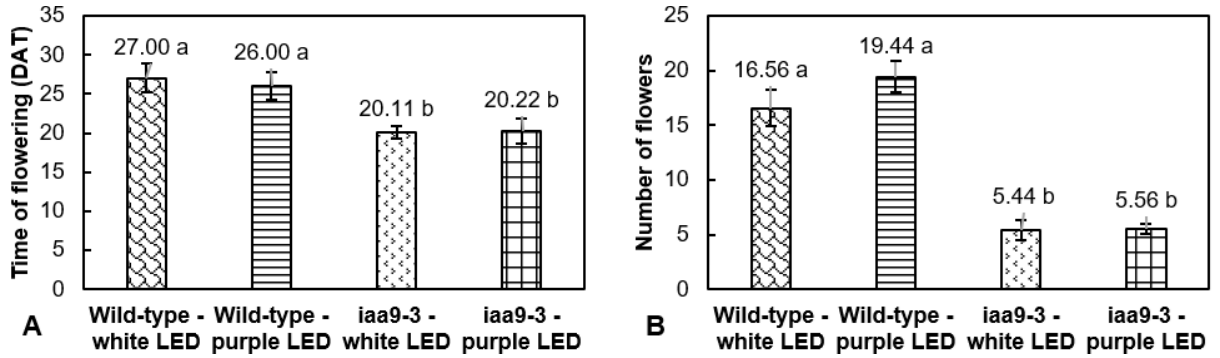

Figure 4. Time of flowering (a) and number of flowers (b) of the wild-type and iaa9-3 tomatoes at different LEDs. The number of flowers is the total number of flowers during the generative period to harvest.

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it does not affect chlorophyll content (Ajdanian et al., 2020). Several sugars accumulate when photosynthates are not evenly translocated to other plant organs (Upreti et al., 2014). Supplementing with LED light that has a higher red-to-blue spectrum ratio has been proven to increase glucose and fructose synthesis in cucumber plant leaves (Wang et al., 2021).

Fruit Contents of Total Soluble Solids, Total Titrated Acids, Glucose, Fructose, and Malic Acid

Glucose-fructose content (Table 1) in the fruits accumulated higher in the purple LED treatment compared to the White LED. However, the differences between LED types and tomato varieties were not significant. The total soluble solute (TSS) content of fruits from the purple LED treatment showed a higher value. In contrast, the highest total titrated acid (TTA) content was found in the WT purple, where TTA levels exceeding 1% can lead to an acidic taste in tomatoes. One of tomatoes' most abundant organic acids is malic acid, with the highest malic acid content found in WT White. However, the difference was not significant compared to other treatments.

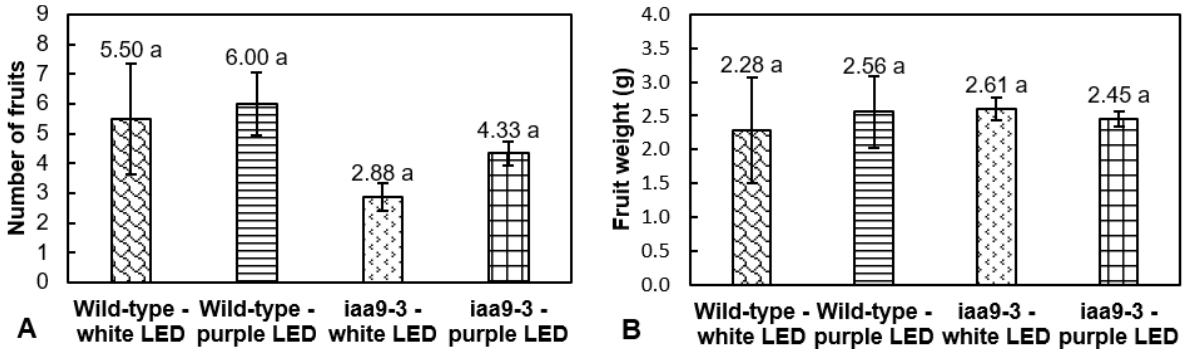

Figure 5. Number of fruits from the appearance of the first to the last fruit (A) and average fruit weight (B) of the wild-type and iaa9-3 tomatoes at different LED treatments.

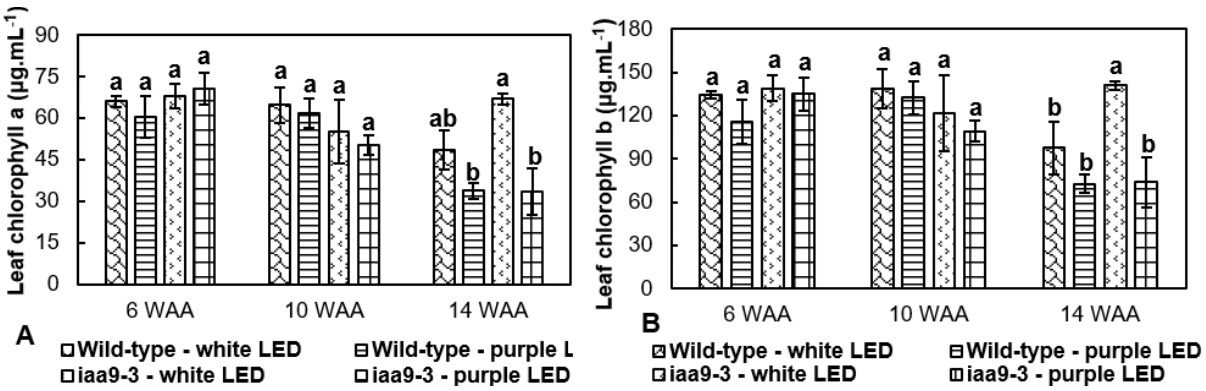

Figure 6. Leaf chlorophyll a (a) and chlorophyll b (b) of the wild-type and iaa9-3 tomatoes at different LEDs. WAA: weeks after the LED application.

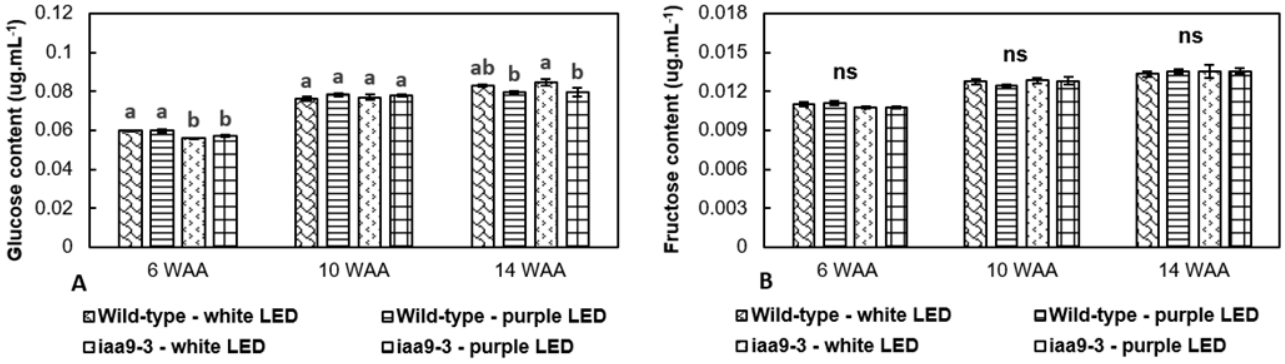

Figure 7. Leaf glucose (a) and fructose (b) of the wild-type and iaa9-3 tomatoes at different LEDs.

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Factors influencing the TSS and TTA values of fruits include climatic conditions, cultivation techniques, plant genetics, fruit ripeness, and harvest age. In a study by Choi et al. (2015), strawberry "Daewang" treated with LED showed similar levels of organic acids, including oxalic, malic, and citric acid, across all treatments. The glucose and fructose content of fruit is higher in purple LEDs (a combination of red and blue light) than in white LEDs, as also reported in dragon fruits (Huang et al., 2022).

Secondary Metabolite Profiling

The results of secondary metabolite profiling in micro-tom tomato leaves (Table 3) showed that 46 compounds were identified from various compound groups. Secondary metabolite profiling (Table 2) shows that the dominant compound class comes from the fatty acids group, followed by saccharides, phenylpropanoids, alkaloids, amino acids, and peptides. The most abundant compound is malic acid. Several compounds from the polyketides group act as a plant defense response against pathogen infection (Monjil et al., 2014). Other identified secondary metabolite compounds, such as D-galactose from the group of Saccharide compounds, which are specific to blue light, play a role in components that form plant cell walls (Uehara et al., 2014). Another secondary metabolite compound specific to red or blue light is trehalose, which functions as plant resistance to abiotic stress (Kosar et al., 2019). Apart from malic acid, the second most abundant compound is 2-C-methylerythritol 4-phosphate, a key compound in the MEP pathway, also known as the non-mevalonate pathway. This compound is important in isoprenoid biosynthesis in plants, certain bacteria, and apicomplexans (a group of parasitic protozoa). Isoprenoids are a large group of organic compounds that play essential roles in various biological processes. Plant hormones, which include isoprenoids, are gibberellin and abscisic acid, pigments, which include isoprenoids, namely carotenoids and chlorophyll, as well as structural components or sterols (Eisenreich et al., 2004). Some isoprenoids synthesized via the MEP pathway function as secondary metabolites, playing a role in plant defense against pathogens and herbivores (Perez-Gil et al., 2024).

Under certain growth conditions, plants produce secondary metabolite compounds that are influenced by physiological processes, which increase when plants experience stress. The formation of secondary metabolite compounds is a physiological adaptive

Table 1. Glucose-fructose content, TSS-TTA, and malic acid content in tomato fruits

Treatments	Glucose ($\mu g.mL^{-1}$)	Fructose ($\mu g.mL^{-1}$)	Total soluble solids (% Brix)	Total titrated acids (% Acidity)	Malic acid ($mg.mL^{-1}$)
Wild-type – white LED	2.43 ± 0.12 a	0.26 ± 0.01 a	8.52 ± 0.10 a	1.85 ± 0.15 a	0.69 ± 0.29 a
Wid-type – purple LED	2.81 ± 0.01 a	0.27 ± 0.00 a	9.23 ± 0.16 a	2.09 ± 0.21 a	0.54 ± 0.11 a
iaa9-3 – white LED	1.78 ± 0.15 a	0.19 ± 0.02 a	5.86 ± 0.21 b	1.96 ± 0.15 a	0.58 ± 0.05 a
iaa9-3 – purple LED	2.53 ± 0.04 a	0.26 ± 0.00 a	6.21 ± 0.14 b	1.75 ± 0.16 a	0.63 ± 0.05 a

Notes: Values followed by the same letter within the same column are not significantly different according to the DMRT at the 5% level

Table 2. Secondary metabolite compounds in Micro-Tom tomato leaves under purple LED treatment

No.	Compound groups	Number of compounds	Abundance (%)	
			Wild-type	iaa9-3
1	Fatty Acids	15	21.99	22.46
2	Saccharides	7	7.92	8.42
3	Phenylpropanoids	6	5.55	4.16
4	Alkaloids	6	5.07	6.20
5	Amino acids and peptides	3	7.50	3.48
6	Polyketides	3	42.08	21.70
7	Flavonoids	2	8.17	5.49
8	Triterpenoids	2	0.41	1.98
9	Monoterpene	1	0.81	0.71
10	Diterpenoids	1	0.47	0.39

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response in plants to stress and defensive stimuli (Isah, 2019). The accumulation of secondary metabolite compounds in plants generally occurs due to physical or chemical factors, as well as the influence of microbes and elicitors, which stimulate the increased synthesis of secondary metabolites in plant parts such as roots, leaves, fruit, flowers, and seeds (Thakur et al., 2019).

Applying blue LEDs to stevia can increase the content of secondary metabolites, including phenolics, flavonoids, and antioxidants; however, this does not correlate with increased growth biomass (Ahmad et al., 2015). Fatty acids serve as biosynthetic compounds that plants use to synthesize phospholipids and glycolipids, which are essential for forming plant organelles, such as seeds. These organelles play a crucial role in the flow and accumulation of photosynthesis from its source to its destination. Apart from that, fatty acids also play a role in plant defense against pathogens, detoxifying plant metabolism, and responding to biotic stress (Jeon et al., 2020).

The implications of this study are that using LED lights as a substitute for sunlight and as supplemental lighting can enhance the growth of Micro-Tom tomatoes. By extending light exposure, particularly for long-day plants, LED lighting can significantly improve growth and development, accelerate the life cycle, and result in earlier harvests. The limitation of this study is the absence of a control group without LED treatment for comparison. In the future, it is hoped that this research can be continued and further developed by incorporating additional light spectra, using varying light intensities, and applying the treatment to other tomato varieties and other horticultural crops.

Table 3. Compound groups of secondary metabolites identified using LC-MS/MS in Micro-Tom tomato leaves under purple LED treatment

No	Name of compounds	Compound groups	Abundance (%)	
			wild-type	iaa9-3
1	Malic acid	Polyketides	40.84	20.53
2	2-C-methylerythritol 4-phosphate	Fatty acids	12.24	13.12
3	Rutin	Flavonoids	7.72	5.49
4	Galactose	Saccharides	4.21	2.08
5	Citric acid	Fatty acids	3.97	1.34
6	Glutamine	Amino acids and Peptides	3.47	-
7	3-(Hydroxymethyl)-4-[3-(beta-D-glucopyranosyloxy)-1-butenyl]-5,5-dimethyl-2-cyclohexene-1-one	Amino acids and Peptides	2.41	1.75
8	Acetyltryptophan	Alkaloids	1.88	4.28
9	Salicylic acid	Phenylpropanoids	1.74	1.74
10	2-Hydroxy-3-(phosphonooxy)propyl (9Z,12Z,15Z)-9,12,15-octadecatrienoate	Phenylpropanoids	1.64	-
11	Fumaric acid	Alkaloids	1.63	0.77
12	Tryptophan	Amino acids and Peptides	1.62	1.73
13	Traumatic Acid	Fatty acids	1.36	2.09
14	Trehalose	Saccharides	1.31	0.87
15	Quinic acid	Phenylpropanoids	1.23	0.99
16	Arabic acid	Saccharides	1.17	0.84
17	Corchorifatty acid F	Fatty acids	0.97	1.27
18	3-O-Feruloylquinic acid	Phenylpropanoids	0.94	0.72
19	(15Z)-9,12,13-Trihydroxy-15-octadecenoic acid	Fatty acids	0.86	0.94
20	4-Hydroxy-3-(3-methyl-2-buten-1-yl)phenyl 6-O-[(2R,3R,4R)-3,4-dihydroxy-4-(hydroxymethyl) tetrahydro-2-furanyl]-β-D-glucopyranoside	Monoterpene	0.81	0.71
21	Butopyronoxyl	Polyketides	0.80	1.17
22	Gluconic acid	Saccharides	0.65	0.52

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23	Benzyl gentiobioside	Saccharides	0.58	0.74
24	9-HpODE	Fatty acids	0.51	0.54
25	13(S)-HpOTrE	Fatty acids	0.50	0.60
26	Tentoxin	Fatty acids	0.49	0.55
27	Atractyloside A	Diterpenoids	0.47	0.39
28	Nicotiflorin	Flavonoids	0.45	-
29	4-Oxoproline	Alkaloids	0.45	-
30	Dehydroascorbic acid	Polyketides	0.44	-
31	Tyrosine	Alkaloids	0.42	0.36
32	Ethyl glucuronide	Triterpenoids	0.41	-
33	1-linoleoyl-sn-glycero-3-phosphoethanolamine	Fatty acids	0.37	-
34	6-Hydroxy-5-methyl-4,11-dioxoundecanoic acid	Fatty acids	0.36	-
35	13(S)-HOTrE	Fatty acids	0.36	0.35
36	Indoleacetylaspartate	Alkaloids	0.35	0.79
37	Phenylbutazone	Alkaloids	0.34	-
38	Kresoxim-methyl	Phenylpropanoids	-	0.37
39	A-12(13)-EpODE	Fatty acids	-	0.33
40	Glyerophosphoinositol	Fatty acids	-	0.37
41	Diphenol glucuronide	Triterpenoids	-	1.98
42	1-Palmitoyl-2-hydroxy-sn-glycero-3-PE	Fatty acids	-	0.54
43	2-Hydroxy-2-methyl-3-buten-1-yl beta-D-glucopyranoside	Phenylpropanoids	-	0.34
44	Jasmonic acid	Fatty acids	-	0.42
45	Glucose 6-phosphate	Saccharides	-	0.44
46	Glucose	Saccharides	-	2.93

Conclusions

The response to providing purple LED versus white LED in Micro-Tom tomatoes did not show significant differences in growth and production parameters. However, significant differences were observed in the types of tomato, the wild-type, and iaa9-3. No significant differences were observed between LED treatments or tomato types in terms of physiological parameters, such as chlorophyll and glucose-fructose levels. Regarding fruit quality parameters, values for TSS-TTA, glucose-fructose, and malic acid also showed no significant differences. Micro-tom tomatoes, as a model plant for research, can help study responses across growth, physiology, and production to metabolomics.

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