The Effect of Supplementary Lighting with LED Lamps on the Growth and Yield of Three Cherry Tomato Hybrids

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Abstract:

A greenhouse experiment was carried out in Babil Governorate, located at 44°E longitude and 32°N latitude Iraq, during the 2024–2025 growing season to evaluate the response of three F1 cherry tomato hybrids to supplemental LED lighting with respect to total yield and physiological quality parameters. The factorial experiment incorporated two factors within a strip-plot arrangement under a randomized complete block design (RCBD) with three replications. The primary factor comprised three lighting treatments: a red and blue LED configuration white LED lighting, and a control without supplemental lighting, applied horizontally as main plot levels. The secondary factor consisted of three cherry tomato hybrids—red spherical, red black, and red bearded assigned vertically within subplots. Hybrids were randomly distributed across replicates, with each replicate including all hybrid types under the same lighting condition. Treatment means were statistically evaluated using the least significant difference (LSD) test at the 0.05 probability level.

The findings indicated that the hybrid (red spherical) exhibited significantly greater plant height and yield per plant, with a maximum mean of 1.36 kg per plant, compared to the other hybrids. No significant differences were detected among the hybrids in terms of leaf area, total leaf number, dry leaf biomass, or auxin and gibberellin concentrations in the foliage. The lighting treatment (red:blue, 18:2) significantly outperformed both white led and control in promoting plant height, leaf production, leaf area, per-plant yield, and endogenous auxin and gibberellin levels. However, lighting treatments did not result in significant variation in vegetative dry mass. Concerning the interaction effects, no significant differences emerged for plant height, leaf number, vegetative dry weight, or gibberellin content. Yet, the H1 × L1 interaction produced the highest values for both leaf area and yield per plant, while the H2 × L1 combination recorded the highest leaf auxin content among the interaction groups.

Keywords: LED Light, Supplementary Lighting, Yield, Cherry tomato.

Introduction:

Cherry tomatoes (Solanum lycopersicum var. cerasiforme) are widely cultivated due to their superior fruit quality, characterized by a sweet flavor that distinguishes them from larger table tomato cultivars [8]. Their global popularity is attributed to their vibrant coloration, distinctive aroma, palatable taste, and notable nutritional and health-promoting attributes [2]. These fruits are especially valued for their rich content of vitaminsparticularly A, B-complex, and C—and for their concentration of bioactive compounds such as lycopene, beta-carotene, folic acid, as well as essential mineral nutrients including phosphorus, potassium, magnesium, and calcium [5]. Compared to conventional tomatoes, cherry tomatoes contain elevated levels of organic acids,

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vitamin C (ascorbic acid), lycopene, and beta-carotene. For instance, their ascorbic acid content has been reported to be approximately 1.7 times higher than that of standard tomatoes [27, 26.[

Plant growth and productivity are profoundly influenced by environmental parameters, particularly light, which serves as the primary energy source for photosynthesis. In addition to driving energy assimilation, light affects various physiological processes including cell division, chlorophyll biosynthesis, tissue development, and stomatal regulation. Light parameters such as intensity, duration, and spectral composition play pivotal roles in these biological functions [24.[

In this context, Light-Emitting Diode (LED) technology has gained prominence in controlled-environment agriculture due to its energy efficiency, longevity, and ability to deliver spectral compositions tailored to specific crop requirements [3]. LEDs have demonstrated higher energy conversion efficiency and operational durability compared to conventional lighting systems [19], and have become an environmentally sustainable lighting solution for greenhouse crop production [9]. Previous studies have confirmed that LED-based supplemental lighting across various developmental stages can substantially enhance crop growth quality ([25, 11]. Furthermore, LEDs have been recognized as an effective means of stimulating growth and development in tomatoes and other horticultural crops [16, 12.[

[10]demonstrated that red and blue LED supplementation accelerated tomato harvesting by 17 days and increased yield by 2.6 times under protected cultivation conditions. Similarly, [23] evaluated the impact of red-to-blue LED lighting (2:7 ratio) applied under different treatment schedules—morning, evening, and no-light control—on tomato plant growth. Results indicated that both morning and evening lighting significantly enhanced plant height compared to the control, while evening treatment led to the greatest improvements in leaf area and stem diameter. These findings underscore the potential of light spectral quality to influence vegetative growth parameters and productivity in tomato crops. Accordingly, the present study aims to assess the impact of light quality on growth characteristics and yield performance in three cherry tomato hybrids.

Materials and Methods:

A field experiment was conducted in Babil, province of Iraq to demonstrate the response of three cherry tomato hybrids to the effects of supplemental lighting during the 2024-2025 growing season under protected environment conditions. The land allocated for the experiment was divided into three sectors, each completely isolated from the others to ensure light penetration from one sector to the next. Each sector contained nine treatments, each containing nine plants. The plants were planted in a staggered planting pattern, with a distance of 60 cm between each plant. Therefore, the area of the experimental unit was 1.8 m², and the number of plants for the experiment was 270. The lighting was connected to the first sector, which was an agricultural LED (red 18: blue 2) lamp. The white LED light was in the second sector, and the last sector was left unlit as a comparison. To generate electricity and ensure 8 hours of electricity during the dark period (night), the lighting was connected to an electric generator (inverter). Cherry tomato hybrid seeds were planted in special trays to prepare the nursery

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on October 5, 2022, and were transferred to the field on November 5, 2022. The patching process was carried out seven days after planting, with all the continuous maintenance operations carried out throughout the plant's life, including weed removal and irrigation. The research was conducted as a factorial experiment using a strip plot design according to a randomized complete block design (RCBD) with three replicates. The experiment included two factors. The first factor included three types of agricultural lighting: LED Plant Growth (Red 18: Blue 2), white LED, and no lighting (comparator). These were symbolized as (L1, L2, L3), respectively, and were placed horizontally as levels for the main plots. The second factor included the study of three (F1) hybrids of cherry tomatoes (Red Spherical, Red Black, and Red Bearded). These were symbolized as (H1, H2, H3). The two hybrids, H1 and H3, were imported from Spain (Barcelona) by the company Semillas Fito SA, while the hybrid H2 was imported from Italy by the company Tera Seeds, and were placed vertically as levels for the sub-plots. The hybrids were randomly distributed within each replicate under a specific lighting type, with each replicate containing the three hybrids under the same lighting type. The treatment means were compared using the least significant difference (LSD) test at a probability level of 0.05. Plant height (cm), leaf area (dm2 plant-1), total number of leaves (leaf plant-1), shoot dry weight (g plant-1), plant yield (kg plant-1), and leaf content of auxins and gibberellins (µg g-1 fresh weight) were determined using a spectrophotometer according to the method used by [21]. 1 g of plant tissue was taken, finely crushed, and filtered. 12 ml of methanol, 5 ml chloroform, and 3 ml ammonium hydroxide were added, the volume was made up to 25 ml of distilled water, and the pH of the solution was adjusted to 2.5 using drops of 1 N hydrochloric acid or 1 N sodium hydroxide, and the samples were read.

Results:

The data presented in Table 1 indicate that the cherry tomato hybrids had a statistically significant impact on plant height. Among them, the H1 hybrid (red spherical) exhibited the greatest plant height, averaging 2.34 m, significantly surpassing the other two hybrids. However, no notable differences were observed among the hybrids in terms of leaf area, total leaf count, or vegetative dry mass.

With respect to supplemental lighting, the L1 treatment (red:blue LED at an 18:2 ratio) significantly outperformed both the L2 (white LED) and L3 (control) treatments, yielding the highest averages in plant height (2.38 m), number of leaves per plant (32.33), and leaf area (18.86 dm^2 per plant). Nevertheless, lighting treatments did not produce significant differences in vegetative dry weight. Concerning factor interactions, plant height, leaf number, and vegetative dry mass were not significantly influenced. However, the H1 × L1 interaction produced the largest average leaf area (20.26 dm^2 per plant), outperforming most treatment combinations.

According to Table 2, hybrid H1 also significantly exceeded hybrids H2 (reddish-black) and H3 (red bearded) in yield per plant, recording the highest mean value of 1.36 kg per plant. No significant differences were found among the hybrids regarding auxin and gibberellin levels in the leaves. As for light quality, treatment L1 once again led to superior performance, achieving the highest averages in yield (1.33 kg per plant), auxin content (10.52 µg g^{-1} fresh weight), and

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gibberellin content (12.87 µg g^{-1} fresh weight), compared to L2 and L3. In terms of interaction effects, the H1 × L1 combination produced the highest per-plant yield (1.69 kg). For auxin content, the H2 × L1 interaction yielded the highest value (11.42 µg g^{-1} fresh weight), while no significant interaction effect was noted for gibberellin levels.

Table 1. Effect Hybrids and LED Supplementary lighting in Plant height (cm), Leaves number (leaf plant-1), Leaf area (dcm2 plant-1) and Dry weight of vegetative system (gm plant-1(

Plant height (m)				
Hybrids Cherry Tomatoe				Supplementary lighting
SL average	Plum Tomato (H3)	blackish red Spherical (H2)	Spherical (H1)	
2.38	2.28	2.30	2.57	LED Red18-Blue2 (L1)
2.17	2.12	2.17	2.23	LED White (L2)
2.18	2.14	2.16	2.23	Without lighting (L3)
	2.18	2.21	2.34	Hybrids average
Iinteraction= N.S.		SL= 0.08	Hybrids= 0.11	LSD (P≤0.05)
Leaves number (leaf $plant^{-1}$)				
Hybrids Cherry Tomatoe				Supplementary lighting
SL average	Plum Tomato (H3)	blackish red Spherical (H2)	Spherical (H1)	
32.33	32.67	30.67	33.67	LED Red18-Blue2 (L1)
30.33	30.33	29.67	31.00	LED White (L2)
30.89	31.67	29.33	31.67	Without lighting (L3)
	31.56	29.89	32.11	Hybrids average
Interaction= N.S.		SL= 1.40	Hybrids= N.S.	LSD (P≤0.05)
Leaf area (dcm^2 $plant^{-1}$)				
Hybrids Cherry Tomatoe				Supplementary lighting
SL average	Plum Tomato (H3)	blackish red Spherical (H2)	Spherical (H1)	
18.86	18.52	17.80	20.26	LED Red18-Blue2 (L1)
17.65	18.15	17.92	16.90	LED White (L2)
18.14	17.51	17.57	19.36	Without lighting (L3)
	18.06	17.76	18.84	Hybrids average
Interaction= 1.66		SL= 0.70	Hybrids= N.S.	LSD (P≤0.05)
Dry weight of vegetative system (gm $plant^{-1}$)				
Hybrids Cherry Tomatoe				Supplementary lighting
SL average	Plum Tomato (H3)	blackish red Spherical (H2)	Spherical (H1)	
700.23	710.58	691.62	689.50	LED Red18-Blue2 (L1)

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698.01	700.63	705.59	687.82	LED White (L2)
701.41	696.70	713.80	693.74	Without lighting (L3)
	702.64	703.67	693.35	Hybrids average
Interaction= N.S.		SL= N.S.	Hybrids= N.S.	LSD (P≤0.05)

Table 2. Effect Hybrids and LED Supplementary lighting in Total yield (kgm plant-1) and Auxins and Gibberellins content in leaves (µg•g⁻ ¹ fresh weight(

Total yield (Kgm plant^{-1})				
Hybrids Cherry Tomato				Supplementary lighting
SL average	Plum Tomato (H3)	blackish red Spherical (H2)	Spherical (H1)	
1.33	1.06	1.25	1.69	LED Red18-Blue2 (L1)
1.02	0.89	0.88	1.28	LED White (L2)
0.96	0.87	0.90	1.12	Without lighting (L3)
	0.94	1.01	1.36	Hybrids average
Iinteraction= 0.17		SL= 0.11	Hybrids= 0.09	LSD (P≤0.05)
Auxin (µg·g⁻ ¹ fresh weight)				
Hybrids Cherry Tomato				Supplementary lighting
SL average	Plum Tomato (H3)	blackish red Spherical (H2)	Spherical (H1)	
10.52	10.04	11.42	10.10	LED Red18-Blue2 (L1)
9.45	9.20	9.53	9.61	LED White (L2)
8.88	9.08	8.61	8.95	Without lighting (L3)
	9.44	9.85	9.56	Hybrids average
Interaction= 1.18		SL= 0.49	Hybrids= N.S.	LSD (P≤0.05)
Gibberellins (µg·g⁻ ¹ fresh weight)				
Hybrids Cherry Tomato				Supplementary lighting
SL average	Plum Tomato (H3)	blackish red Spherical (H2)	Spherical (H1)	
12.87	13.10	12.19	13.33	LED Red18-Blue2 (L1)
11.09	11.01	11.14	11.11	LED White (L2)
11.23	11.26	11.25	11.18	Without lighting (L3)
	11.79	11.53	11.87	Hybrids average
Interaction= N.S.		SL= 0.81	Hybrids= N.S.	LSD (P≤0.05)

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Discussion:

The hybrids did not differ significantly among themselves in leaf area, total leaf number, dry weight of the vegetative mass, and leaf content of auxins and gibberellins. However, the hybrid H1 (globular red) significantly outperformed the hybrids H2 (blackish red) and H3 (bearded red) in plant height. Regarding yield, the same hybrid, H1 (globular red), significantly outperformed the hybrids H2 (blackish red) and H3 (bearded red) in yield per plant and produced the highest average. The lack of significant differences may be due to genetic makeup and the ability of different varieties to adapt to different greenhouse conditions [17], and thus not to their influence. As for the differences that occur among hybrids in plant height and yield per plant, this is primarily due to the variation in their genetic makeup, which affects their physiological capacity and efficiency in converting the results of photosynthesis to cell growth, elongation, and division, which is reflected in growth indicators. Vegetative, in other words, the vegetative and floral growth indicators are mainly controlled by genetic factors and are influenced by environmental factors that affect the growth indicators of these genetic structures [1, 4]. The reason for these differences is mainly due to the difference in their genetic content, as each structure expresses the trait to a significant degree, in addition to the environmental influence with which these structures interact in ways that differ from one structure to another [6]. Or to the interaction of genetic factors with the surrounding environment that affects the performance of hybrids, as the trait is controlled by a large number of genes and their effect is of the secondary type, which makes them greatly affected by the environment, and then creates a second effect, which is the interaction between the environment and genetics [13]. This is what [7] found when they studied three cherry tomato hybrids (yellow, orange, and red), and they found Red cherry tomatoes significantly outperformed the other two hybrids in total yield per unit area, with no significant difference between hybrids in total leaf chlorophyll content. Regarding the type of supplemental LED lighting, treatment L1 (red 18:blue 2) significantly outperformed both L2 (white LED) and L3 (no lighting), yielding the highest average plant height, leaf number, leaf area, yield per plant, and leaf content of auxins and gibberellins. However, there was no significant difference between the light types in the dry weight of the plant's foliage. This is due to the fact that light quality plays a vital role as a signaling mechanism in regulating photosynthesis, photomorphogenesis, and various other plant responses [22], which is reflected in its effect on increasing vegetative growth indicators, yield, and leaf chemical content. Red light is known to play an important role in stimulating stem elongation, regulating phytochrome responses, and inducing changes in plant anatomical structure [18], thus increasing plant height. Meanwhile, blue light is important in chlorophyll synthesis, stomatal opening, enzyme synthesis, chloroplast maturation, and photosynthesis [20]. Furthermore, light acts as a mechanism for transmitting signals through various photoreceptors and provides the energy needed for plant growth and development [15], thereby affecting leaf number and leaf area, thereby increasing the efficiency of photosynthesis, which ultimately leads to increased plant yields. [14] demonstrated that

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blue or red light alone cannot meet the requirements of plant growth and development, and therefore, their combination plays a significant role in enhancing plant growth.

Conclusions:

The hybrids did not differ significantly in all vegetative growth indicators, except for plant height, which was distinguished by the red spherical tomato, outperforming the other two hybrids. The same hybrid also outperformed the other two hybrids in both per-plant yield and leaf auxin and gibberellin content. The lack of significance may be attributed to the genetic closeness between the parents used in the hybridization program, which leads to reduced genetic variation in the second generation. Alternatively, these traits may be controlled by a large number of genes with small effects (quantitative inheritance), making it difficult to detect clear differences. The use of supplementary lighting, especially red-blue LEDs, on an important economic crop like tomato is an important factor in enhancing plant growth and development and its impact on photosynthesis, a vital process that supplies the plant with the nutrients it needs for its growth.

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