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Influence of light spectrum and photoperiod on yield and quality parameters of chilli (*Capsicum Annuum* L.) under indoor vertical farming

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ABSTRACT

The present investigation, entitled "Influence of Light Spectrum and Photoperiod on Yield and Quality Parameters of Chilli (*Capsicum annuum* L.) under Indoor Vertical Farming" was conducted to evaluate the influence of different LED light spectra and photoperiod combinations on the yield and quality parameters of chilli under controlled indoor vertical farming conditions. The experiment comprised two chilli varieties, namely Thai chilli and Bullet chilli, subjected to five light treatments consisting of different red and blue LED light ratios under varying photoperiods. Significant differences were observed among the treatments and varieties for yield and quality attributes. The Bullet chilli variety exhibited superior performance in terms of fruit number, individual fruit weight and yield per plant under favourable light conditions. Among the light treatments, the 1R:2B LED spectrum combined with a 16-hour photoperiod promoted better vegetative growth and contributed to improved yield performance, while the 1R:2B LED spectrum with a 14-hour photoperiod resulted in better fruit production and yield attributes compared with the control. The different light spectrum and photoperiod combinations also influenced quality parameters of chilli, including chlorophyll and ascorbic acid content. The findings indicate that optimization of LED light quality and photoperiod can effectively enhance yield and quality characteristics of chilli under indoor vertical farming conditions. These results highlight the potential application of LED-based lighting strategies for improving productivity and quality of chilli in indoor vertical farming and speed-breeding systems.

Keywords: Chilli (*Capsicum annuum* L.), LED light spectrum, Photoperiod, Indoor vertical farming, Yield, Fruit quality, Red and blue light, Chlorophyll, Ascorbic acid, Speed breeding

1. Introduction

Chilli (*Capsicum annuum* L.) is one of the most important vegetable and spice crops belonging to the family Solanaceae. It is widely cultivated in tropical and subtropical regions and is valued for its characteristic pungency, colour, flavour and nutritional properties. Chilli fruits are consumed both as fresh vegetables and in processed forms such as dried chilli, chilli powder, sauces and various food products. The crop is an important source of vitamins, minerals, antioxidants and bioactive compounds, particularly capsaicinoids, carotenoids, vitamin C and phenolic compounds. The productivity and quality of chilli are influenced by genotype, environmental conditions, nutrient availability, temperature, light intensity, light spectrum and photoperiod. Under controlled cultivation systems such as indoor vertical farming, manipulation of environmental factors, particularly artificial lighting, provides an opportunity to regulate plant growth, flowering, fruit development and yield. Therefore, understanding the response of chilli to different light spectra and photoperiods is important for developing efficient production strategies under controlled environments.

Average fruit weight is an important yield-attributing trait that reflects the extent of fruit development and contributes directly to the total yield of chilli plants. It is influenced by genetic characteristics of the variety as well as environmental factors such as light, temperature, water availability and nutrient supply. Adequate light availability promotes photosynthetic activity and assimilate production, which supports the development and accumulation of dry matter in fruits. The spectral composition of artificial light can also influence plant morphology, flowering, fruit set and assimilate partitioning, thereby affecting individual fruit weight. In indoor vertical farming, the use of red and blue LED combinations provides an opportunity to manipulate light quality according to crop requirements. Differences in average fruit weight among varieties and light treatments can therefore indicate the effectiveness of particular light environments in supporting fruit development. Evaluation of average fruit weight is consequently essential for assessing the influence of LED spectrum and photoperiod on the productivity and marketable quality of chilli. (Abbas *et al.*, 2025) ^[1]

Yield per plant is a major indicator of crop productivity and represents the combined effect of several yield components, including number of fruits per plant, fruit size and individual fruit weight. In chilli, yield is influenced by genetic potential, flowering behaviour, fruit set, nutrient availability and environmental conditions throughout the growing period. Light is particularly important because it provides the energy required

for photosynthesis and regulates several developmental processes associated with flowering and fruit production. Red and blue wavelengths are strongly involved in photosynthetic activity, plant architecture, flowering and biomass accumulation, while photoperiod influences the duration of light exposure available for photosynthesis and plant development. Under indoor vertical farming, controlled manipulation of light spectrum and photoperiod can improve the efficiency of light use and potentially enhance fruit production. Therefore, yield per plant is an important parameter for determining the suitability of specific LED light combinations and photoperiods for improving chilli productivity under controlled growing conditions. (Appolloni *et al.*, 2021) [2]

Chlorophyll content is an important physiological parameter associated with the photosynthetic capacity and overall functional status of plants. Chlorophyll pigments, mainly chlorophyll *a* and chlorophyll *b*, absorb light energy required for photosynthesis and play a fundamental role in the conversion of light energy into chemical energy. The concentration of chlorophyll can be influenced by genotype, nutritional status, environmental conditions and the quality and intensity of light received by plants. Red and blue wavelengths are particularly important in regulating chlorophyll formation and photosynthetic processes, making them significant components of LED lighting systems used in controlled-environment agriculture. Higher chlorophyll content may support greater photosynthetic activity and carbohydrate production, which can contribute to improved vegetative growth and reproductive performance. Measurement of chlorophyll content under different LED spectra and photoperiods therefore provides useful information on the physiological response of chilli plants to artificial lighting and helps in understanding the relationship between light environment, photosynthetic potential and crop productivity. (Jimenez-Viveros *et al.*, 2023) [3]

Ascorbic acid, commonly known as vitamin C, is an important nutritional and antioxidant compound present in chilli fruits and contrib-

utes significantly to their dietary value. It plays important roles in human nutrition, including antioxidant protection and support of normal physiological functions. The concentration of ascorbic acid in chilli fruits is influenced by genotype, fruit maturity, environmental conditions, temperature, nutrient availability and light exposure. Light is particularly important in regulating the synthesis and accumulation of several primary and secondary metabolites involved in fruit quality. Changes in light spectrum and photoperiod can alter photosynthetic activity and carbon assimilation, potentially influencing the accumulation of vitamin C and other antioxidant compounds in developing fruits. Under indoor vertical farming, controlled LED lighting provides an opportunity to manipulate the light environment and evaluate its effect on nutritional quality. Therefore, estimation of ascorbic acid content is an important quality parameter for determining how different LED light spectra and photoperiods influence the nutritional value of chilli fruit. (Kabir, 2020) [4]

2. Materials and Methods

The present investigation entitled “*Influence of Light Spectrum and Photoperiod on Yield and Quality Parameters of Chilli (Capsicum annum L.) under Indoor Vertical Farming*” was conducted during the year 2025–2026 at Urban Kisaan Private Limited, Gundlapochampally, Hyderabad, Telangana, India. The experiment was carried out under a controlled indoor cultivation system to evaluate the influence of different light spectrum and photoperiods on the growth and flowering performance of chilli. Two chilli varieties, namely Thai chilli and Bullet chilli were subjected to varying combinations of red and blue LED light treatments under 14-hour and 16-hour photoperiods. The materials employed and the experimental procedures adopted for conducting the study are described in the following sections



Figure 1. Overall Experimental Plot

2.1 Experimental design

The experiment was laid out in a Factorial Completely Randomized Design (FCRD) with ten treatments and 3 replications. Each treatment consisted of 30 plants established in pots arranged across vertical layers. One plant pot were randomly selected and tagged for recording observations. Planting was carried out during the last week of August 2025. Throughout the study period, uniform cultural practices were followed across all treatments. In each treatment, ten uniformly healthy plants were randomly selected for recording observations in each replication. The mean value for each parameter was calculated based on data recorded from selected plants.

Table 1. Treatment details

Treatments	Cultivars	
	Thai chilli	Bullet chilli
T ₁	1R:2B+14 hr duration	1R:2B+14 hr duration
T ₂	1R:2B+16 hr duration	1R:2B+16 hr duration
T ₃	2R:1B+14 hr duration	2R:1B+14 hr duration
T ₄	2R:1B+16 hr duration	2R:1B+16 hr duration
T ₅	Control	Control

(continued on next page)



Figure 2. Chilli Growth under LEDs

3. Results and discussion

3.1 Average fruit weight (g)

The results of the analysis of variance indicated that the treatment effects were highly significant, demonstrating considerable variation among the treatment combinations for the character under study. Among all the treatments, T_6 recorded the highest mean value (1.80 g), followed closely by T_7 (1.74 g). Since the difference between these two treatments was lower than the critical difference ($CD = 0.32$), they were found to be statistically at par and significantly superior to the remaining treatments. T_4 (1.08 g), T_8 (1.06 g), T_1 (1.05 g) and T_2 (1.05 g) formed the next superior group and were statistically

comparable with one another. T_9 recorded a moderate mean value (0.90 g), whereas T_3 (0.73 g) exhibited relatively lower performance compared to the superior treatments. The minimum mean value was observed in T_5 (0.26 g), which was statistically at par with T_{10} (0.30 g), indicating non-significant variation between these two treatments. Overall, the significant differences observed among the treatments clearly revealed the influence of the treatment combinations on the experimental parameter. The coefficient of variation (18.85%) further indicated satisfactory precision and reliability of the experimental findings. Similar results were observed by (Zhao *et al.*, 2025) [5] in tomatoes.

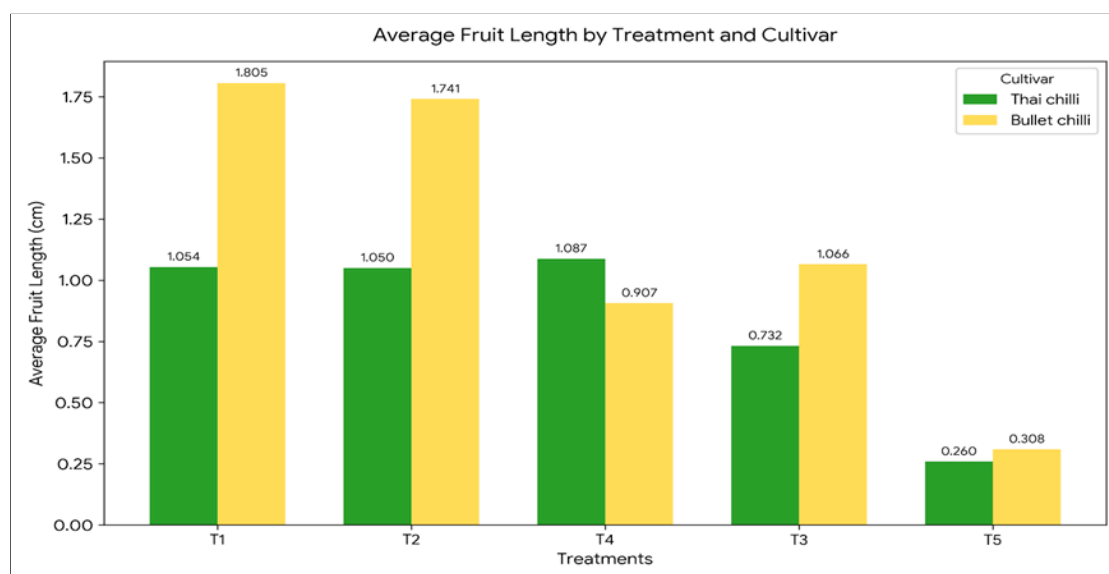
3.1 Illustrative representation of Average fruit weight (g) variation among chilli varieties grown in indoor farming systems

Table 3.1. Effect of light treatments on Average fruit weight (g) of chilli Top of Formi:

TREATMENTS		Average fruit weight (g)		
		Thai chilli (C ₁)	Bullet chilli (C ₂)	Mean
T_1	1R:2B+14 Hours of light	1.05	1.80	1.43
T_2	1R:2B+16 Hours of light	1.05	1.74	1.39
T_3	2R:1B+14 Hours of light	0.73	1.06	0.89
T_4	2R:1B+16 Hours of light	1.08	0.90	0.99
T_5	Control (White light)	0.26	0.30	0.28
	Mean	0.83	1.16	
		SEm±	CD (5%)	
	Cultivars (C)	0.04		0.14
	Light treatments (L)	0.07		0.22
	CXL	0.10		0.32

T_1, T_6 -1R:2B+14 Hours duration
 T_2, T_7 -1R:2B+16 Hours duration

T_3, T_8 -2R:1B+14 Hours duration



T₄, T₉ -2B:1B+16 Hours duration

T₅, T₁₀ -Control

3.2 Yield per plant (g)

The analysis of variance revealed that the treatment effects were significant ($F = 5.11$, $p < 0.01$), indicating the existence of considerable variation among the treatment combinations for the parameter under study. Among the ten treatments evaluated, T₆ recorded the highest mean value (3.07 g), followed by T₇ (2.30 g). However, the difference between these two treatments was non-significant, as the mean difference was lower than the critical difference value ($CD = 1.00$), indicating that both treatments were statistically at par. T₁ (1.95 g) also showed comparatively better performance and remained statistically comparable with T₇, T₂, T₈, and T₉. T₂ (1.55 g), T₈ (1.33 g), T₉ (1.22

g) and T₃ (1.07 g) exhibited moderate performance and did not differ significantly from one another. T₄ (0.88 g), T₅ (0.71 g), and T₁₀ (0.70 g) recorded comparatively lower mean values and were statistically at par due to differences smaller than the critical difference value. The lowest mean value was observed in T₁₀ (0.70 g). Overall, the significant treatment effect indicated that the treatment combinations exerted a measurable influence on the experimental trait. The coefficient of variation (39.49%) suggested relatively higher experimental variability, although the treatment differences remained statistically significant. Similar results were observed by (Appolloni *et al.*, 2022) [6] in tomatoes.

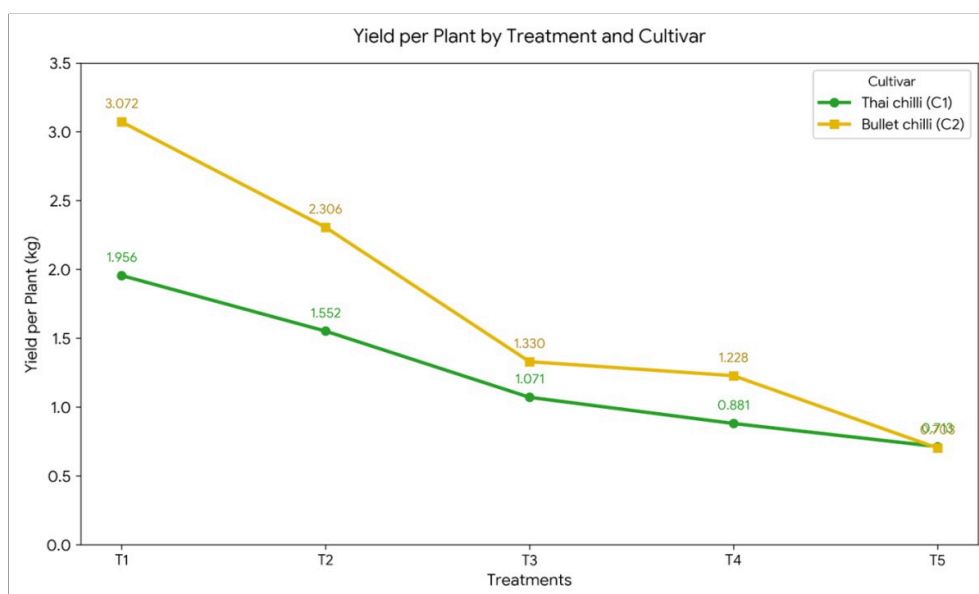
3.2 Illustrative representation of Yield per plant (g) variation among chilli varieties grown in indoor farming system

Table 3.2. Effect of light treatments on yield per plant (g) in chilli

TREATMENTS		Yield per plant (g)		
		Thai chilli (C ₁)	Bullet chilli (C ₂)	Mean
T ₁	1R:2B+14 Hours of light	1.95	3.07	2.51
T ₂	1R:2B+16 Hours of light	1.55	2.30	1.92
T ₃	2R:1B+14 Hours of light	1.07	1.33	1.20
T ₄	2R:1B+16 Hours of light	0.88	1.22	1.05
T ₅	Control (White light)	0.71	0.70	0.70
Mean		1.23	1.72	
		SEm±		CD (5%)
Cultivars (C)		0.15		0.61
Light treatments (L)		0.23		0.97
CXL		0.33		1.37

T₁, T₆ -1R:2B+14 Hours duration

T₂, T₇ -1R:2B+16 Hours duration



T₃, T₈ -2R:1B+14 Hours duration
 T₄, T₉ -2B:1B+16 Hours duration

T₅, T₁₀ -Control



(a)
 (b)

3.3 Chlorophyll content

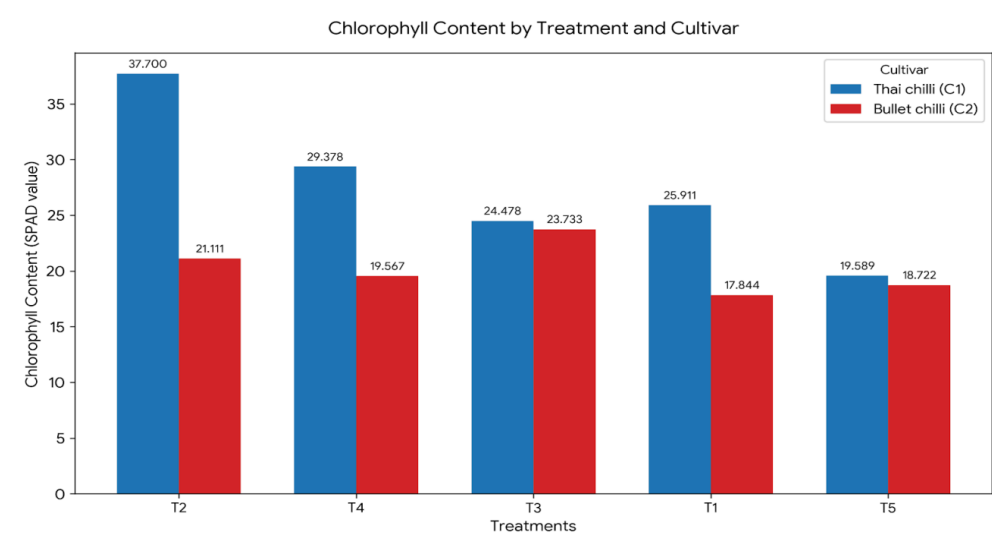
The analysis of variance revealed that the treatment effects were highly significant ($F = 6.37$, $p < 0.01$), indicating the existence of considerable variation among the treatment combinations for the character under investigation. Among the ten treatments, T₂ recorded the highest mean value (37.70) and was found to be significantly superior to all other treatments, as the differences exceeded the critical difference value (CD = 7.16). T₄ (29.37) recorded the next highest mean value and remained statistically at par with T₁ (25.91), T₃

(24.47), and T₈ (23.73), since the differences among them were less than the CD value. T₁ also showed comparable performance with T₃ and T₈. T₇ (21.11), T₅ (19.58), T₉ (19.56), T₁₀ (18.72), and T₆ (17.84) recorded comparatively lower mean values and were statistically at par with one another. The lowest mean value was observed in T₆ (17.84), which did not differ significantly from T₁₀, T₉, T₅, and T₇. Overall, the significant treatment effect indicated that the treatment combinations had a marked influence on the parameter studied. The coefficient of variation (17.538%) suggested acceptable precision and reliability of the experimental data. Similar results are observed by (Mori *et al.*, 2026) [7] in egg plant.



Plate 4. (a) Average fruit weight (b) Yield per plant

3.3 Illustrative representation of total Chlorophyll content variation among chilli varieties grown in indoor farming system



T₁, T₆ -1R:2B+14 Hours duration

Table 3.3. Effect of light treatments on chlorophyll content in chilli Top of Formi

TREATMENTS		Chlorophyll content		
		Thai chilli (C ₁)	Bullet chilli (C ₂)	Mean
T ₁	1R:2B+14 Hours of light	25.911	17.844	21.878
T ₂	1R:2B+16 Hours of light	37.700	21.111	29.406
T ₃	2R:1B+14 Hours of light	24.478	23.733	24.106
T ₄	2R:1B+16 Hours of light	29.378	19.567	24.472
T ₅	Control (white light)	19.589	18.722	19.156
	Mean	27.411	20.196	
		SEm±	CD (5%)	
	Cultivars (C)	1.078		3.203
	Light treatments (L)	1.704		5.064
	CXL	2.410		7.161

T₂, T₇ -1R:2B+16 Hours duration

T₃, T₈ -2R:1B+14 Hours duration

T₄, T₉ -2B:1B+16 Hours duration

T₅, T₁₀ -Control

3.4 Ascorbic acid content (mg)

The analysis of variance revealed that the treatment effects were highly significant ($F = 30.48$, $p < 0.01$), indicating substantial variation among the treatment combinations for the character under study. Among the ten treatments evaluated, T₁ recorded the highest mean value (119.53 mg), followed by T₂ (114.9 mg), T₃ (110.55 mg), and T₄ (109.92 mg). Since the differences among these treatments were less than the critical difference value (CD = 11.36), they were found to be statistically at par with each other. T₅ (104.44 mg) and T₉ (104.65 mg) also exhibited comparable performance and remained statistically similar to T₃ and T₄. T₁₀ recorded a mean value of

(102.91 mg) and was statistically at par with T₅ and T₉. In contrast, T₆ (79.70 mg), T₇ (66.13 mg), and T₈ (59.17 mg) recorded significantly lower mean values than the superior treatments. Among these, T₈ registered the lowest mean value and was statistically at par with T₇, whereas T₆ was significantly superior to T₇ and T₈. Overall, the treatment combinations differed significantly in their influence on the experimental parameter, with T₁ producing the highest response, although it remained statistically comparable with T₂, T₃, and T₄. The relatively low coefficient of variation (6.81%) indicated high experimental precision and reliability of the observed results. Similar results were observed by (Wittmann *et al.*, 2025) [8] in chilli.



(a)



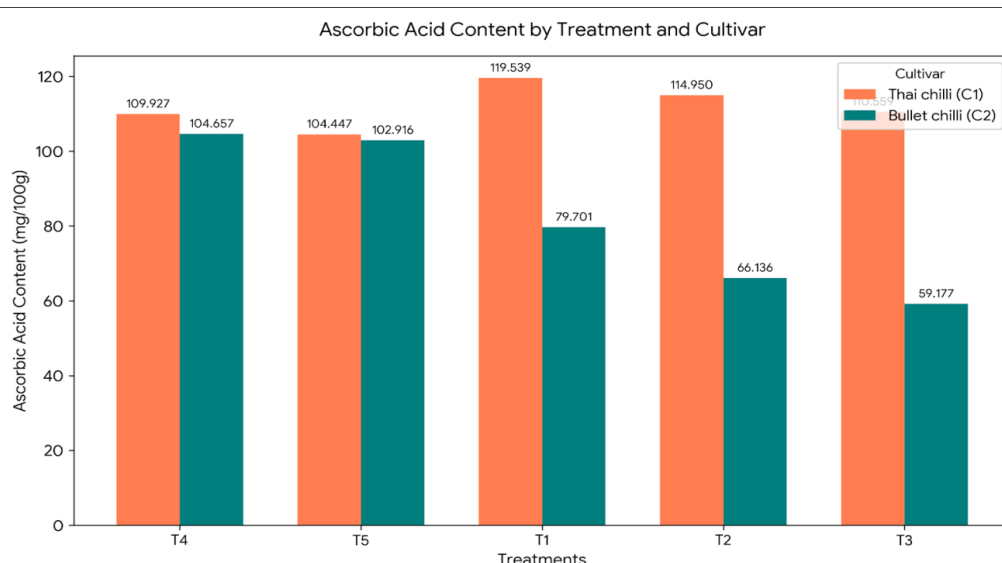
(b)

Plate 5. (a) checking chlorophyll content (b) sending sample for ascorbic acid test

3.4 Illustrative representation of Ascorbic acid content (mg) variation among chilli varieties grown in indoor farming systems

Table 3.4. Effect of light treatments on Ascorbic acid content (mg) in chilli Top of Form

TREATMENTS		Ascorbic acid content (mg)		
		Thai chilli (C ₁)	Bullet chilli (C ₂)	Mean
T ₁	1R:2B+14 Hours of light	119.53	79.70	99.62
T ₂	1R:2B+16 Hours of light	114.95	66.13	90.54
T ₃	2R:1B+14 Hours of light	110.55	59.17	84.86
T ₄	2R:1B+16 Hours of light	109.92	104.65	107.29
T ₅	Control (White light)	104.44	102.91	103.68
Mean		111.88	82.51	
		SEm±	CD (5%)	
Cultivars (C)		1.71		5.08
Light treatments (L)		2.70		8.03
CXL		3.82		11.36



T₁, T₆ -1R:2B+14 Hours duration
 T₂, T₇ -1R:2B+16 Hours duration
 T₃, T₈ -2R:1B+14 Hours duration
 T₄, T₉ -2R:1B+16 Hours duration
 T₅, T₁₀ -Control

Conclusion

The present investigation demonstrated that LED light spectrum and photoperiod significantly influenced the yield and quality parameters of chilli grown under indoor vertical farming conditions. Among the treatments, the 1R:2B spectrum with a 14-hour photoperiod (T₁, T₆) recorded the highest average fruit weight and yield per plant, with Bullet chilli (T₆) showing the maximum values of 1.80 g and 3.07 g, respectively. The 1R:2B spectrum with a 16-hour photoperiod (T₂/T₇) resulted in the highest chlorophyll content, particularly in Thai chilli (T₂), which recorded 37.70. For ascorbic acid, Thai chilli (C₁) recorded the highest value of 119.53 mg under T₁, while the highest treatment mean (107.29 mg) was observed under 2R:1B + 16 hours (T₄/T₉). Overall, Bullet chilli exhibited superior performance for yield-related traits, whereas Thai chilli recorded higher chlorophyll and ascorbic acid content. The findings indicate that optimizing red and blue LED light spectra with suitable photoperiods can effectively improve the productivity and quality of chilli under indoor vertical farming systems.

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