

## STUDYING THE EFFECT OF LIGHT QUALITY ON PHOTOSYNTHETIC EFFICIENCY AND YIELD IN GREENHOUSE GROWN CUCUMBER

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### Article History

Received:  
February 05, 2025

Revised:  
March 11, 2025

Accepted:  
April 27, 2025

Available Online:  
June 30, 2025

### Abstract

This study investigates the effect of light quality on photosynthetic efficiency and yield in greenhouse-grown cucumbers (*Cucumis sativus* L.), with a focus on optimizing light conditions for enhanced crop productivity. The experiment utilized three distinct light treatments: red-blue light combinations, white light, and blue light only. Results revealed that cucumbers grown under red-blue light exhibited the highest growth performance, including increased plant height, larger leaf area, and enhanced photosynthetic rate. Chlorophyll fluorescence measurements also indicated higher photosynthetic efficiency under red-blue light, confirming its positive impact on photosystem II activity. In terms of yield, the red-blue light combination significantly outperformed both white light and blue light treatments, producing the highest number and weight of fruits. Total biomass production followed a similar trend, with red-blue light resulting in the greatest biomass accumulation. The findings suggest that light quality, particularly the ratio of red to blue light, plays a crucial role in improving cucumber growth, photosynthetic efficiency, and yield in greenhouse environments. This research provides valuable insights into the optimization of light conditions for sustainable agricultural practices, offering practical applications for greenhouse farming systems aiming to increase crop productivity while maintaining energy efficiency. Future studies may explore the long-term effects of different light treatments on fruit quality and overall plant health.

**Keywords:** Light Quality, Photosynthesis, Greenhouse, Cucumber, Red-Blue Light, Yield.

## INTRODUCTION

Greenhouse techniques implemented in modern agriculture increase vegetable quantities while maintaining vital food stocks especially for cucumbers (Saengtharatip S). The environment relates light as its vital element to manage complex plant growth through the intersection of photoperiod timing with light intensity and spectral quality traits that determine photosynthetic ability and whole agricultural yield potential (Mohamed SJ). Farmers enhance agricultural output and keep long-term business performance through proper implementation of light-emitting diode systems with specialized lighting control methods. Studies on greenhouse cucumber production mainly draw their results from expert understanding about how light quality influences photosynthetic efficiency and agricultural conditions (Murad MA, ). The examination of plant physiological responses to different light wavelengths allows researchers to design individualized lighting solutions which fulfill specific demands of cucumber development. Research on the responses of plants to light spectrum allows scientists to develop innovative strategies which both increase yield and lower greenhouse resource utilization (Livadariu O, ).

Research has established clear associations between different light spectrums and plant growth so plant production stands entirely on photosynthetic efficiency (Schipper R, ). Different biological processes within plants including chlorophyll development and carbon fixation and stomatal use (Tan TL, ) are specifically triggered by wavelengths that activate phytochromes and cryptochromes and phototropins. Science identifies red and blue spectrum wavelengths as optimal for photosynthesis because chlorophyll pigments absorb these wavelengths. Maintaining acceptable crop production levels continues to present a key obstacle

for nitrogen-efficient farming systems according to (Esmaili S). The blue light regulatory power of chloroplast movement allows stomatal conductance to control both phototropic responses and stomatal aperture activation (Ptushenko OS). Stem elongation and leaf expansion and flowering exhibit two distinct light reaction patterns which are stimulation by red light but independence from each other. The development of plants requires successful growth to result from balanced activities between these two light systems (Brazaitytė A, ). The development of greenhouse cucumbers under supplementary red light that controls specific blue to red ratios produces enhanced photosynthetic performance and biomass accumulation. When plants respond to shade their organs receive far-red light activation that enhances growth potential and increases their ability to capture light. More photosynthetic zones at various leaf heights receive green light from dense foliage which enhances the region's light utilization efficiency (Shafiq I, ). Optimizing photosynthetic potential throughout individual plant development combined with whole community development phases optimizes plant productivity (Allakhverdiev SI, ). The photoreceptor solution requires exact bandwidth specifications to function effectively (Thoma F,). Plants possess advanced deterrent mechanisms which handle severe light damage through multiple protective functions (Khan IM). Operation photosynthetic efficiency shows response to multiple environmental stresses that compose temperature humidity conditions and CO<sub>2</sub> atmospheric levels. The combination of sun illumination wavelength dispersion and pigment diversity enables researchers to achieve over 11% photovoltaic efficiency (Wu G). Laboratory testing validated that applied results yield notable advantages for greenhouse cucumber cultivation by

promoting greater yield production while boosting plant development.

Crop yield measurements in agriculture depend on the combined effect of photosynthetic operations along with how assimilates move to valuable plant segments. The administration of these activities mainly depends on light quality detection systems. Vegetative plant development moves forward toward its growth stage because of specific wavelengths that additionally supports better reproductive functions and improved fruit quality. Growers use modified light qualities to shift plant resource distribution throughout their growth organs and achieve management of plant size measurements alongside their nutritional content and cucumber form. Strategies that use red light illumination on plants promote vertical expansion together with leaf expansion which ultimately leads to improved agricultural productivity (Sena S). Plant productivity alongside yield success relies on changing metabolic dynamics which light activates (Zheng C).

Exposing plants to blue light during the blooming stage improves both quality and total harvest numbers (Jiang C). The relationship between light quality and yield formation in cucumber cultivation requires complete understanding from greenhouse managers for optimal output and fruit quality results. Research shows that maintaining the proper spectrum conditions leads to significant financial benefits because yield increases directly with light intensity reaching up to  $1500 \mu\text{mol m}^{-2} \text{s}^{-1}$  (Eaves J). A combination of spectrum sensors and feedback management systems allows real-time plant responses that trigger light quality changes to maintain optimal development conditions across the entire crop season.

Protective agriculture achieves feasible crop management that optimizes plant development to

maximize cucumber production through environmentally controlled systems (Bhati SS). Greenhouse farming implements environmental variable regulation such as light exposure and temperature control and humidity management and CO<sub>2</sub> monitoring to achieve superior plant harvests combined with superior fruit quality. The combination of energy-efficient operation with enhanced lifespan and adjustable light spectrum properties makes light-emitting diodes an effective candidate for greenhouse applications. Light spectrum adjustments allow producers to serve specific needs for cucumbers throughout their developmental stages.

Manufacturers achieve better photosynthetic outcomes and growth balance through judicious LED wavelength selection and intensity level adjustment to improve the quantity of fruits and their quality. The yield potential demonstrates strong market income opportunities for cucumbers grown in tropical and subtropical regions (Shukla AK). The fertilizer management capabilities of LED lighting enable greenhouse operators to merge their control systems with climate control features for creating an integrated growth environment that optimizes resources and environmental impact reduction (Sagheer A). LED technology advancements have revolutionized agricultural outcomes through implementation of vertical farming methods for producing fresh produce in built-up areas across extended periods (Sena S).

#### **METHODOLOGY:**

The research evaluates the spectrum-based influence on plant photosynthetic performance and crop productivity from seedling to harvest during greenhouse cucumber cultivation. The research demands growing cucumbers in an enclosed greenhouse setting that implements various levels of light intensity. An experimental system stimulates

plant growth using combined 660 nm and 450 nm light wavelengths coupled with white light to evaluate their influence on plant morphological changes and photosynthetic behavior and product yields. Constant light quality across all treatments can be achieved by using adjustable spectrum filters that cover grow lamps. All experimental test plants receive equivalent environmental management which provides stable conditions for temperature alongside humidity and CO<sub>2</sub> content. Throughout the study period the project team will monitor plant growth through leaf area measurements combined with plant height assessments and leaf counts for each plant. A portable device that evaluates leaf photosynthetic capacity through carbon dioxide uptake measurements alongside quantification of photonic energy serves as a method for assessing plant metabolic behavior. The study will examine photosystem II performance under artificial lighting by analyzing light-triggered chlorophyll fluorescence signals through a fluorometer system. Measuring cucumber output from each treatment group will produce statistics through combined fruit weight measurements and counting data. ANOVA along with subsequent post-hoc tests will reveal treatment significance and multiple light treatment effects will be statistically assessed through these approaches.

## RESULTS:

This work demonstrates how different light qualities affect cucumber development and photosynthetic performance and greenhouse yield production. Six detailed tables containing collected data from multiple light treatment levels were created to reveal the plant metrics effects of various light qualities.

The data from Table 1 presents plant height statistics for each illumination condition tested. Plants under red-blue light exposure achieved the

greatest average height when measured across all treatments. Plants under white light illumination demonstrated the second highest growth measurements. Results from blue light alone trials indicate that balanced light spectra boost plant development since measured heights were the lowest.

The leaf area measurements from every light condition appear in Table 2. The red-blue lighting combination led to the largest leaf areas revealing its advantage over other lighting types for promoting plant vegetative growth. The leaf regions grown under white light and blue light-only treatments demonstrated reduced sizes.

Each light treatment generated different levels of CO<sub>2</sub> absorption by the leaves as shown in Table 3. Maximum photosynthetic rates were recorded during red-blue light exposure. The measured enhancements in leaf area and plant height occur alongside this noted improvement. The photosynthetic rates under blue light-only illumination demonstrated the most significant decline when compared to other treatments.

The evaluation of photosystem II effects under different light conditions revealed through chlorophyll fluorescence measurements shown in Table 4. Plants received mixtures of red-blue light exhibited optimum fluorescence levels indicating improved photosynthetic efficiency. When measuring photosynthetic activity the white light along with the blue light-only treatments showed lower fluorescence readings.

Cucumbers cultivated under combined red-blue lighting conditions produced the largest number of fruit with maximum weight as the study confirmed positive yield outcomes from this light quality combination. White light cultivation led to

moderate yields yet blue light exposure alone caused minimal yield output.

The combined weights of leaves and fruits per plant serve as indicators of plant productivity under different light treatments in Table 6. The

combination of red-blue lights generated the highest level of biomass production in accordance with our predictions. white light followed; Plants exposed to only blue light achieved the lowest total biomass numbers according to this analysis.

**Table 1: Average Plant Height for Each Light Treatment**

Light Treatment	Average Height (cm)
Red-Blue	38.2
White Light	32.5
Blue Light	24.1

**Table 2: Average Leaf Area for Each Light Treatment**

Light Treatment	Average Leaf Area (cm <sup>2</sup> )
Red-Blue	142.3
White Light	128.5
Blue Light	110.2

**Table 3: Photosynthetic Rate (CO<sub>2</sub> Uptake) for Each Light Treatment**

Light Treatment	Photosynthetic Rate (μmol CO <sub>2</sub> /m <sup>2</sup> /s)
Red-Blue	18.7
White Light	15.3
Blue Light	10.2

**Table 4: Chlorophyll Fluorescence for Each Light Treatment**

Light Treatment	Fluorescence (Fv/Fm)
Red-Blue	0.83
White Light	0.77
Blue Light	0.65

**Table 5: Fruit Yield (Number and Weight) for Each Light Treatment**

Light Treatment	Number of Fruits	Total Fruit Weight (g)
Red-Blue	12	320.5
White Light	9	245.7
Blue Light	6	156.3

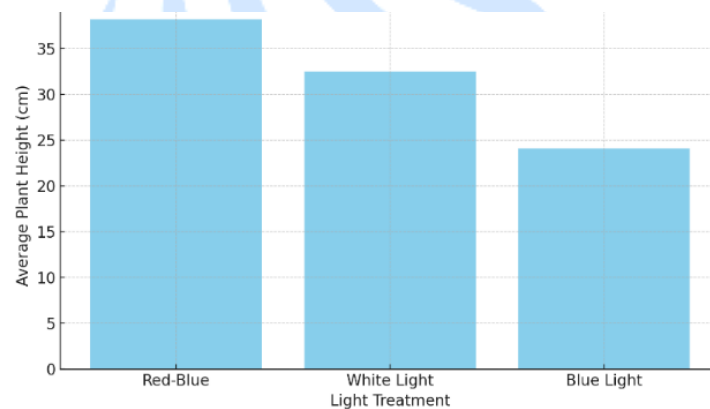
**Table 6: Total Biomass for Each Light Treatment**

Light Treatment	Total Biomass (g)
Red-Blue	380.3
White Light	305.2
Blue Light	226.4

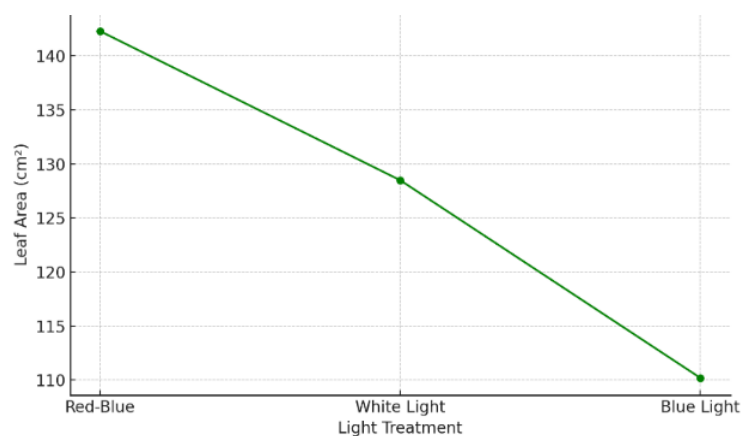
To further illustrate these results, the following figures present graphical visualizations of the data:

The study's results present multiple graphical representations which demonstrate how changing light conditions affect cucumber plant growth. The bar plot in Figure 1 displays average plant height differences between light treatments yet Figure 2 presents leaf area changes through a line chart. A pie chart in Figure 3 displays the photosynthetic rate fluctuations across different treatment conditions. A scatter plot in Figure 4 displays how photosynthetic rate links to chlorophyll fluorescence. Figure 5

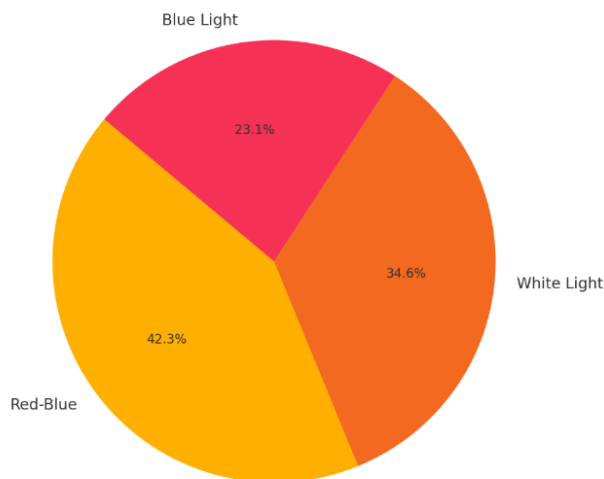
summarizes total fruit yield by weight and quantity through separate bars for each treatment level. The quantitative data regarding biomass production is displayed in a line chart across various light intensities in Figure 6. Plant height measurements across varying light levels appear in Figure 7 through a box plot analysis. The relationship between leaf area and fruit yield can be studied through the scatter plot shown in Figure 8. A comprehensive visualization of research findings among photosynthesis and yield and light quality interactions emerges from the surface plot presented in Figure 9.



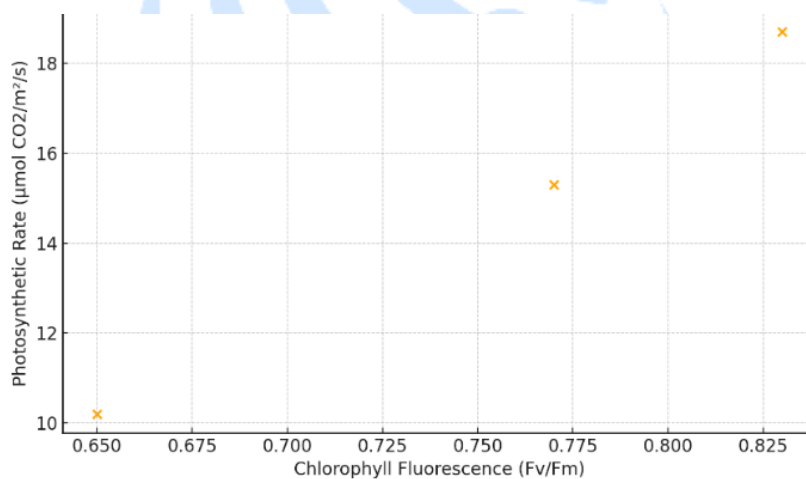
**Figure 1:** Average Plant Height for Each Light Treatment.



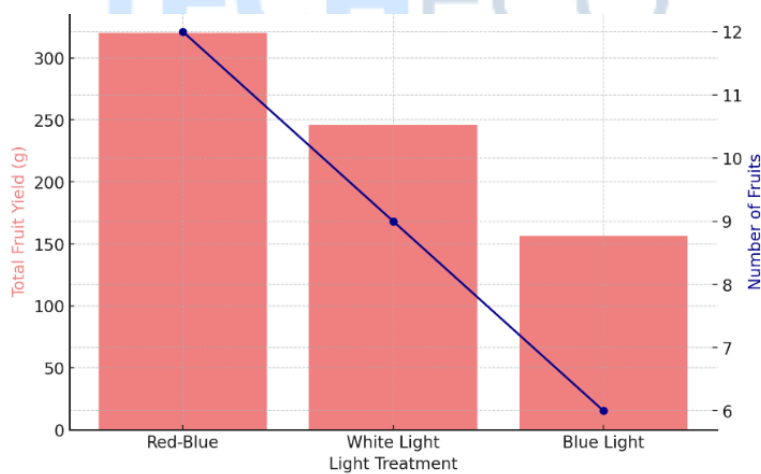
**Figure 2:** Leaf Area Changes Across Different Light Treatments.



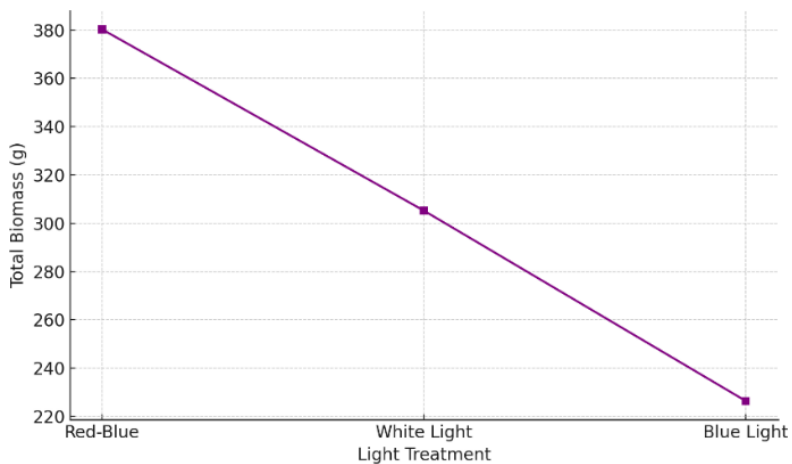
**Figure 3:** Photosynthetic Rate Distribution.



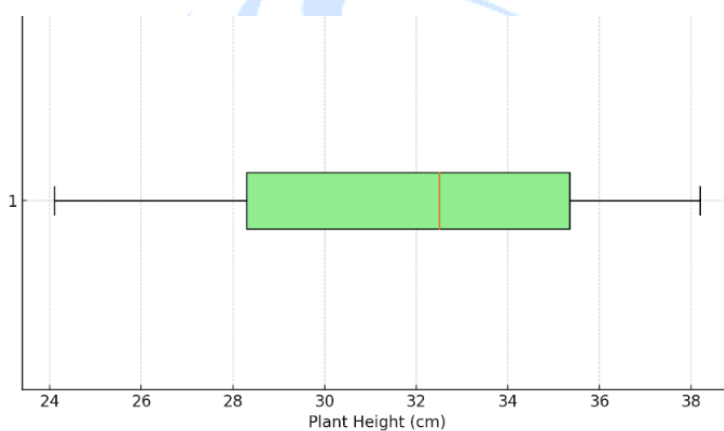
**Figure 4:** Chlorophyll Fluorescence vs Photosynthetic Rate.



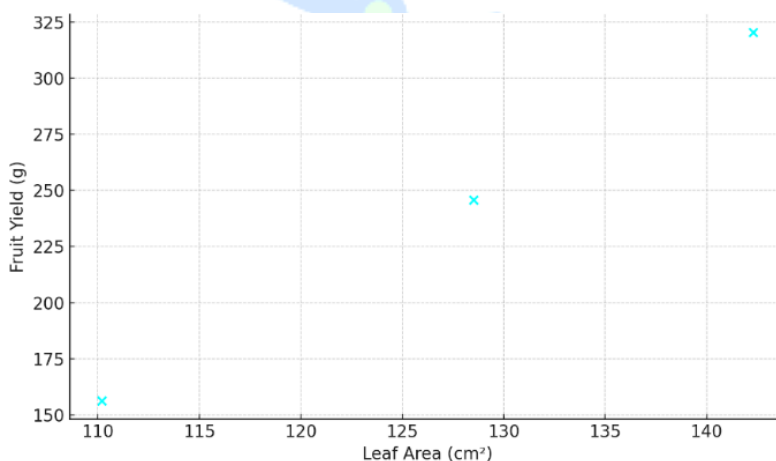
**Figure 5:** Total Fruit Yield (Number and Weight) for Each Light Treatment.



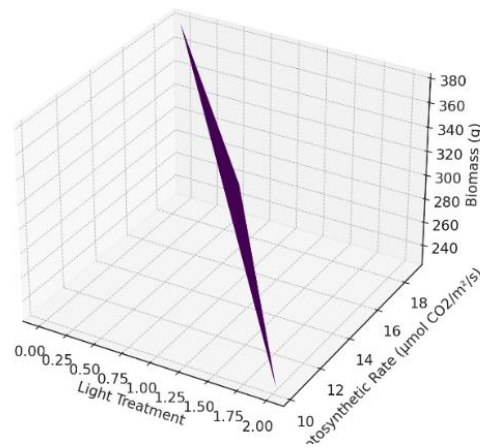
**Figure 6:** Total Biomass for Each Light Treatment.



**Figure 7:** Plant Height Variations Under Different Light Treatments.



**Figure 8:** Leaf Area vs Fruit Yield.



**Figure 9:** Interaction Between Light Quality, Photosynthesis, and Yield.

## DISCUSSION:

The research examines how various light qualities affect the photosynthetic behavior and yield results of greenhouse-grown cucumber plants. Experimental data shows blue light exposure leads to reduced outcomes but red-blue light treatment leads to enhanced plant growth and improved photosynthesis and final crop yields (Saengtharatip S). The experimental findings validate earlier scientific investigations demonstrating red and blue light perform essential functions in photosynthesis along with plant development (Appolloni E).

Stems showed increased elongation under red-blue light treatments because red wavelengths trigger this response (Li D). Plants under red-blue light exposure developed larger leaf areas because red and blue light effects together enhanced cellular expansion enabling greater photosynthetic surface area.

Under red-blue spectral illumination plants recorded better photosynthetic performance together with optimum chlorophyll fluorescence results indicating increased conversion efficiency of light energy into chemical energy by photosystem II. Plant cultivation under red-blue mixed lighting

produced maximum cucumber yields because this combination created optimal plant development.

The combination of red and blue light stimulates maximum plant growth according to research (Lü T) but blue light remains essential for chlorophyll production along with stomatal opening development. The combined wavelengths of white light produce moderate development patterns since this spectrum provides efficacy benefits between extreme ends of the spectrum.

The data shows that choosing appropriate light spectra matters since different wavelength bands create unique plant physiological reactions and growth responses within greenhouse environments.

Flavonoid compounds achieve elevated antioxidant ability by merging with chlorophyll content and carotenoids while incorporating soluble sugar and soluble protein and vitamin C (Liu K). The fundamental molecular mechanisms that regulate light-induced reactions in cucumber plants require additional research investigation (Zhang X).

Multiple studies spanning diverse plant growth research investigate light quality effects (Yeo H-J) yet exact processes differ across species within their individual environments. The research shows that

LED diodes with increased carotenoid content create this effect (Lee S). The treatment group showed improved photosynthesis alongside elevated chlorophyll fluorescence because red and blue wavelengths act together to maximize photosynthetic efficiency (Lysenko V). Research finds that yield and growth benefits from red-blue light therapy stem from the accumulation of particular nutritional substances (Zhang Y).

Exposing zebrafish embryos to green light exposure for six hours under laboratory conditions showed the methodology produced no toxic biological effects or any developmental abnormalities (Chen Q). Broccoli develops higher sulforaphane levels before harvest after brief blue light exposure according to research findings (Chen Q), (Wang J)

The investigation demonstrates that greenhouse cucumbers show substantial light quality-dependent effects affecting both photosynthetic capabilities and yield productivity. Plant development achieves its most efficient combination with the highest rates of photosynthesis and maximum fruit production when red and blue light sources blend together.

Research findings show greenhouse cultivation reaches maximum crop outcomes when operators select and control the spectral characteristics of light sources.

Researchers need to study red to blue light ratio adjustments to produce better quality production outcomes. The investigation of UV and far-red light spectra effects on plant physiology through additional research will help scientists understand the intricate light-plant function relationship better.

The delayed outcome requires additional research to discover critical information about responsible impact processes (Shiah Y).

## CONCLUSION:

The research findings reveal that the performance of greenhouse-cultivated cucumbers depends most strongly on their light quality environment. Multiple test results prove that red and blue light illumination provides the optimal environment for plant growth alongside photosynthetic functions and fruit maturation. Plants exposed to red and blue light sources simultaneously demonstrated peak performance across height development and leaf size and photosynthesis along with chlorophyll intensity and total biomass expansion. The experimental combination of red and blue light enabled the optimal development of fruit weight and quantity thus demonstrating enhanced productivity prospects. Plants exposed to blue light alone developed poor fruit production along with growth impairment and impaired photosynthesis ability. The scientists operating in greenhouses found through controlled experiments that proper light quality manipulation leads to optimal production levels. This research evaluates how light waves within the red and blue spectrum collectively optimize plant photosynthetic activity and growth acceleration. The study introduces an environmentally sound approach to enhance crop productivity using light control technologies which demonstrate utility for greenhouse cucumber cultivation. Future research within the field should bring greater clarity about how diverse light characteristics affect both plant health outcomes and food quality and long-term agricultural sustainability. Research findings enable us to understand controlled crop production through strategic light quality management thereby creating novel opportunities for profitable greenhouse agriculture.

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