THE EFFECT OF DIFFERENT LIGHT WAVELENGTHS ON THE VEGETATIVE GROWTH DYNAMICS OF *Brassica oleracea* L. var. capitata

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Brassica oleracea L.(cabbage) is an extensively cultivated, highly versatile, and nutritious vegetable, thriving in cool climates and requiring full sun exposure for optimal growth. Besides photosynthesis, light regulates many physiological processes, such as photomorphogenesis, phototropism, and circadian rhythms, which affect the overall course of growth and productivity. The objective of this study was to identify the effective visible wavelength that, when given in a supplementary manner, promotes the optimal growth of *B. oleracea***.** The seedlings were exposed to distinct light treatments; Red (600-700 nm), Blue (400-500 nm), and Green (500-600 nm) at night (12-hour duration) for 42 days. The growth of the plants was measured by recording the shoot length, root length, leaf area, and leaf number. The results indicated that there is a significant difference ($p \leq 0.05$) in both shoot length and root length across the light treatments. Notably, seedlings treated with red light exhibited the highest mean shoot length (5.81 ± 1.42 cm) and root length (6.16 ± 1.23 cm) in comparison to the control. Overall, the study concluded that red light had the most significant positive effect on the growth of *B. oleracea* seedlings compared to blue or green light. This suggests that red light may be the most beneficial for promoting shoot and root growth in this particular plant species. Further research could explore the specific mechanisms behind how different light wavelengths affect plant growth, as well as potential applications for optimizing growth in agricultural settings.

Key words: *Brassica oleracea*; Light wavelengths; Plant growth; Red light, LED

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INTRODUCTION

Light is a fundamental factor influencing plant growth and development, serving as the primary energy source for photosynthesis, where plants convert light energy into chemical energy (Smith & Whitelam, 1997). This process is crucial for the synthesis of carbohydrates, essential for plant growth and survival. Beyond photosynthesis, light regulates key physiological processes in plants, including seed germination, stem elongation, leaf expansion, and flowering induction (Franklin & Quail, 2010). Photoreceptors such as phytochromes and cryptochromes perceive light and trigger molecular signalling pathways that govern these developmental processes (Briggs & Christie, 2002).

Different wavelengths of light influence specific aspects of plant growth and development. Red light (600-700 nm) promotes vegetative growth, while blue light (400-500 nm) affects plant morphology and stomatal regulation (Casal & Smith, 1989; Li & Kubota, 2009). Greenlight (500-600 nm) also contributes to photosynthesis and signalling shade conditions within plant canopies (Murchie & Niyogi, 2011). Understanding the interplay between these light wavelengths and plant responses is essential for optimizing growth strategies and enhancing crop productivity. Light availability and quality are crucial in controlled agricultural environments such as greenhouses and indoor farms. Advances in LED (Light Emitting Diode) technology allow precise manipulation of light spectra to meet the specific needs of plants, maximizing growth efficiency and yield potential (Smith & Whitelam, 1997). These innovations are significant for sustainable agriculture, offering opportunities to enhance resource use efficiency, mitigate environmental impact, and ensure food security in a changing climate.

Brassica oleracea L. var. capitata, commonly known as cabbage, is a versatile and widely cultivated vegetable valued for its nutritional and culinary applications. It belongs to the Brassicaceae and is characterized by a compact head of thick leaves, which vary in colour from green to red or purple depending on the cultivar (Franzke *et al*., 2011). Rich in vitamins C, A, and K, as well as dietary fibre, *B. oleracea* is renowned for its health benefits and is commonly used in salads, stir-fries, soups, and fermented dishes like sauerkraut and kimchi (Moreb *et al*., 2020). It thrives in cool climates and well-drained soil, requiring ample sunlight for optimal growth. Its adaptability to various growing conditions and relatively low maintenance makes it a popular choice for both home gardeners and commercial growers.

This study aims to investigate the effects of specific wavelengths of the visible spectrum on the vegetative growth dynamics of *B. oleracea* var. capitata when they were given on a supplementary basis at night. By comparing the influence of various wavelengths given at night with night without supplementary light, this study seeks to determine the most suitable wavelength for maximizing *B. oleracea* growth and identify favourable colour combinations to improve yield. Moreover, this sheds light on plant biology and agriculture by elucidating the specific effects of different light wavelengths administered on a supplementary basis on the growth and development of *B. oleracea*.

METHODOLOGY

Plant Selection and Growth Setup

Healthy *B. oleracea* var. capitata seedlings were selected and planted in transparent pots with a depth of 6 inches. The experimental setup included three treatments and a control, with each treatment and the control replicated across five pots, resulting in a total of twenty pots. Each pot contained four seedlings, totalling eighty plants for the entire experiment. All pots were kept covered with black material and were only uncovered at specific times to take measurements. The pots were filled with nutrient-rich compost to support optimal plant growth. The experiments were conducted in a greenhouse under controlled environmental conditions, with natural sunlight and a constant temperature of 28°C.

Light Treatment

To assess the effects of different light wavelengths, LED lights emitting red (600-700 nm), blue (400-500 nm), and green (500-600 nm) spectra were employed. A control setup without LED lights was also established for comparative purposes. Each treatment group received daily light exposure from 6:00 pm to 6:00 am via LED strips, ensuring consistent light intensity. During the remaining 12 hours, the seedlings were exposed to natural sunlight.

To maintain consistent environmental conditions, the plants under LED light treatments (red, blue, and green) were housed in covered setups to prevent external light interference. The control group remained exposed to natural sunlight throughout the day. Protective nets were used to safeguard the experimental area from pests and rodents, ensuring the integrity of the study.

Plant Growth Parameters

The primary growth parameters measured included shoot length, root length, and leaf area. These parameters were monitored weekly to track growth dynamics. Shoot and root lengths were measured using a standardized ruler. Leaf area was calculated by multiplying the leaf length by the leaf width, with the total leaf area determined using the Montgomery equation (Montgomery, 1911). Additionally, the number of leaves per plant was counted weekly to provide a comprehensive assessment of plant development.

RESULTS AND DISCUSSION

The results indicate a marginally significant difference in shoot length in relation to different light treatments, as evidenced by an F value of 2.643 and a p-value of 0.0562. Although the p-value is slightly above the conventional significance threshold of 0.05, it suggests a trend towards significance, implying a potential effect of colour of the light on shoot length (Figure 1). Conversely, root length exhibits a statistically significant difference among light treatments, indicated by an F value of 3.288 and a p-value of 0.0258. This underscores the influence of hue of the light on root development, with certain wavelengths favouring greater growth (Figure 2). However, there is no significant difference in the number of leaves and leaf area between light treatments, as indicated by relatively low F values (0.726 and 0.518, respectively) and p-values above 0.05 (0.54 and 0.671 respectively).

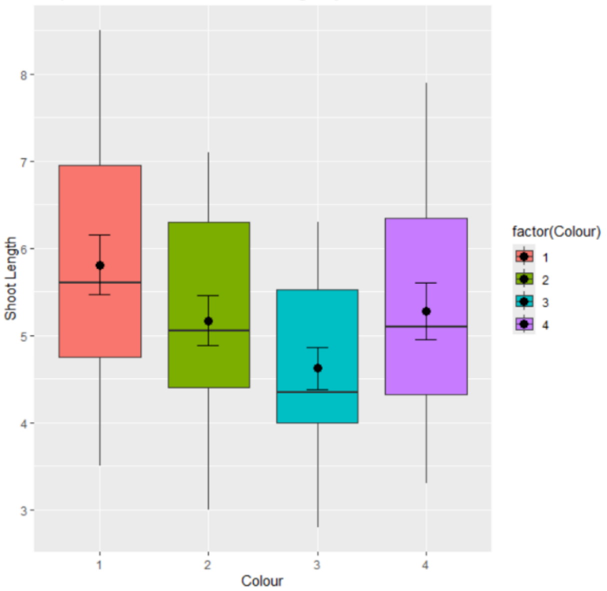

Figure 1. The effect of different wavelengths of the visible spectrum on shoot height of *Brassica oleracea* L. (The x axis of the graph represents the different colours in light: 1=red, 2=blue, 3=green, 4=control, and y axis represent the shoot length in centimetres)

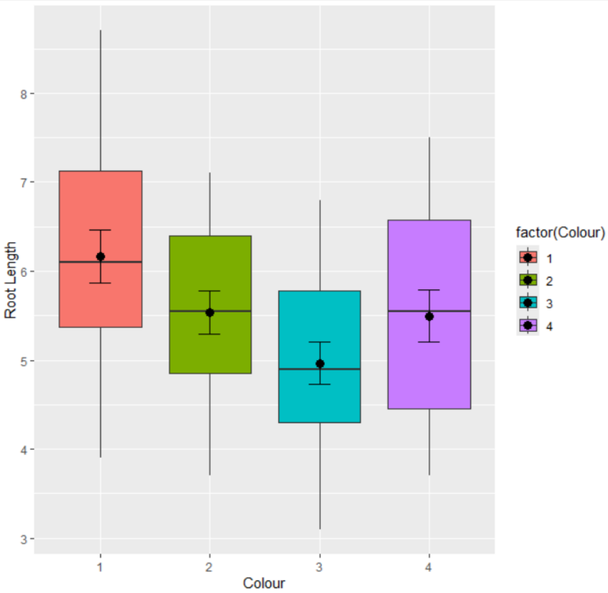

Figure 2. The effect of different wavelengths of the visible spectrum on root length of *Brassica oleracea* L. (The x-axis of the graph represents the different colours in light: 1=red, 2=blue, 3=green, 4=control, and y-axis represent the root length in centimetres)

Among the treatments, the red-light treatment resulted in the highest shoot length (5.81 ± 1.42 cm) and root length (6.16 ± 1.23 cm), followed by the control treatment. The green light treatment exhibited the lowest shoot length (4.62 ± 0.98 cm) and root length (4.96 ± 0.98 cm) among the treatments (Table 1). These findings suggest that red light may have a more favourable effect on both shoot and root growth compared to blue, green, and control conditions. Further analysis is needed to confirm these trends and explore the underlying mechanisms driving the observed differences in plant growth responses to different light treatments.

Table 1. Effect of different light wavelengths on growth parameters of *B. oleracea*

Treatment (Colour)	**Growth Parameters**			
	Mean Shoot Length ± SD (cm)	Mean Root Length ± SD (cm)	Mean Leaf Area ± SD (cm^2)	Mean Leaf No ± SD
Red	5.81 ± 1.42	6.16 ± 1.23	1.66 ± 2.32	3.05 ± 0.97
Blue	5.17 ± 1.16	5.53 ± 0.99	1.29 ± 2.06	2.78 ± 0.78
Green	4.62 ± 0.98	4.96 ± 0.98	0.85 ± 0.99	2.61 ± 0.82
Control	5.27 ± 1.33	5.49 ± 1.20	1.43 ± 2.13	2.83 ± 0.95

The observed highest mean shoot length and mean root length in *B. oleracea* var. capitata plants treated with red light align with previous studies indicating the importance of red light in promoting vegetative growth (Casal & Smith, 1989; Li & Kubota, 2009). This outcome suggests that red light plays a significant role in stimulating shoot and root development, potentially through its influence on key physiological processes such as cell elongation and division (Briggs & Christie, 2002). The significant differences in mean shoot length and mean root length among the four treatment groups (red, blue, green, and control) underscore the distinct effects of different light wavelengths on plant growth and development (Franklin & Quail, 2010; Murchie & Niyogi, 2011). This finding is consistent with the notion that plants perceive and respond differently to various light spectra, leading to variations in growth patterns and morphological traits (Smith & Whitelam, 1997). Moreover, the observed superiority of red-light treatment in promoting shoot and root growth highlights the potential practical implications for optimizing growth conditions in agricultural settings. By harnessing the specific effects of red light, growers may enhance crop productivity and yield by manipulating light environments to favour desired growth outcomes (Williams & Hill, 1986). However, further research is warranted to elucidate the underlying mechanisms driving the differential responses to light wavelengths and to optimize light regimes for specific crop species and varieties.

CONCLUSION

In conclusion, this study demonstrates that supplementary red-light treatment significantly enhances shoot and root growth in *Brassica oleracea* var. capitata compared to green, blue, and control conditions. The superior growth observed under red light suggests its potential as an optimal wavelength for promoting plant development. However, further research is necessary to elucidate the underlying mechanisms driving these responses and to refine light conditions for maximizing plant productivity and yield. These findings have important implications for optimizing growth strategies in controlled agricultural environments.

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