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# Impact of Light Wavelengths on Photosynthetic Rates in Spinach

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

In this study, we investigated the effects of different light wavelengths, specifically red, blue, and green light, on the rate of photosynthesis in plants. Transmittance rates were collected at three-minute intervals over a nine-minute duration, and the photosynthetic rates were calculated for each wavelength. Our findings revealed that the red light wavelength resulted in a higher rate of photosynthesis (2.14%) compared to blue (1.57%) and green light (1.81%). Interestingly, the control group, which represented white light, exhibited the highest rate of photosynthesis at 2.31%. These results suggest that red light is more effective in promoting photosynthesis than blue or green light, and white light may be even more efficient. This information is crucial for understanding optimal growth conditions for plants, particularly in controlled environments such as indoor farms, where light wavelengths can be manipulated to maximize growth rates and crop yields. Further research should focus on comparing the effects of red, white, and other light wavelengths on photosynthesis to determine the most effective wavelength for plant growth and to explore potential synergistic effects of different light combinations.

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## 1. INTRODUCTION

Photosynthesis is a process by which autotrophic organisms convert light energy into chemical energy, which they use to fuel various biological processes. This complex process is crucial for the sustenance of life on Earth, as it forms the basis of the food chain [1,2]. Light energy captured by pigments such as chlorophyll a is converted into chemical energy in the form of ATP and NADPH, which are then utilized in the synthesis of organic molecules such as glucose [3]. The process of photosynthesis involves two main stages: light-dependent reactions, which take place in the thylakoid membrane, and the light-independent reactions, which occur in the stroma of the chloroplasts [4,5].

The primary objective of this study was to investigate the effects of light on the process of photosynthesis, specifically on the rate of light-dependent reactions. The light-dependent reactions involve the absorption of light by photosynthetic pigments, leading to the generation of ATP and NADPH, which are then used to drive the light-independent reactions [6]. In this study, we focused on the reduction of blue light in 2,6-di-chlorophenol-indophenol (DPIP) in spinach leaves as an indicator of the rate of photosynthesis.

The process of photosynthesis can be represented by the equation: $6CO_2 + 6H_2O +$ light energy $\rightarrow C_6H_{12}O_6 + 6O_2$, which shows the transformation of carbon dioxide and water into glucose and oxygen in the presence of light energy [7]. The overall reaction can be divided into two parts: the light-dependent reactions and the light-independent reactions. In the light-dependent reactions, light energy is captured by photosynthetic pigments, leading to the generation of ATP and NADPH, which are used to power the light-independent reactions [8].

It is well established that different wavelengths of light have different effects on the process of photosynthesis. In general, plants absorb light in the red and blue parts of the spectrum most efficiently, while green light is least effective [9]. Color theory suggests that colors opposite to each other on the color wheel are complementary colors, and they tend to enhance each other's brightness when placed next to each other. For example, green and red are complementary colors, and green objects appear brighter when placed against a red background [10]. In the context of photosynthesis, this implies that green objects, such as spinach leaves, would absorb red light more efficiently than green light.

In this study, we aimed to investigate the effects of different wavelengths of light on the rate of photosynthesis in spinach leaves. Specifically, we tested the hypothesis that red light, being complementary to green, would be more effective at promoting photosynthesis than green light. The independent variable in this study was the wavelength of light, while the dependent variable was the rate of photosynthesis, measured as the change in transmittance over time in response to different wavelengths of light.

In order to carry out this study, we employed a spectrophotometer to measure the transmittance of light through spinach leaves in response to different wavelengths of light. We used DPIP, a blue electron acceptor, to monitor changes in the rate of photosynthesis in response to different wavelengths of light. Our findings could have important implications for optimizing photosynthetic rates in plants, which could have significant applications in the field of agriculture. By manipulating the wavelengths of light to which plants are exposed, it may be possible to enhance photosynthetic rates, ultimately leading to higher crop yields and more sustainable food production practices.

In summary, this study aimed to investigate the effects of different wavelengths of light on the rate of photosynthesis in spinach leaves. Our findings could contribute to the development of optimized conditions for plant growth and improved crop yields in controlled environments, such as indoor farms, where light wavelengths can be manipulated. Our data showed that the photosynthetic rate was significantly affected by the color of light, with red light being the most effective at promoting photosynthesis in spinach leaves. This is consistent with the understanding that different colors of light have distinct absorption rates by photosynthetic pigments, which in turn influences the photosynthetic rate. Moreover, we found that white light, as represented by the control condition, may be the most efficient for promoting photosynthesis, suggesting potential practical implications for agricultural practices. Future research should focus on exploring the synergistic effects of different light wavelengths in combination to further refine our understanding of how to optimize photosynthetic performance in plants.

## 2. MATERIALS AND METHODS

Spinach leaves were used in this experiment for the acquisition of chloroplasts. The spinach leaves were initially taken out of the refrigerator and de-vined to remove large pieces of the spinach that had little to no chloroplasts. The chloroplasts were placed underneath a lamp to prime them for photosynthesis. After being primed, the chloroplasts were placed into a chilled blender, cold to preserve the chloroplasts and prevent the rate of photosynthesis from dropping before the experiment. Mixed with 0.5mL of sucrose solution to maintain an isotonic environment, the blender mixed the chloroplasts in three 10 second bursts, to prevent the buildup of heat, in order not to overstimulate, and thus preserve the chloroplasts. The chloroplasts were emptied into a three-layer cheesecloth to sift out large pieces of spinach, and preserve a concentrated solution of chloroplasts.

Transferring the chloroplasts to our lab, we held all materials: DPIP, chloroplasts, distilled water, and the phosphate buffer, in a cooler to preserve the chloroplasts. In a tube rack there were five tubes, of which would be a calibration tube to set the %T to 100% before each testing session, and three chloroplast tubes, a control, a tube under green light, a tube under red light and a tube under blue light. At this time, the spectrophotometer was turned on in order to warm up and prepare for readings. Each tube was filled with a 1mL phosphate buffer to maintain the pH level. In the calibration tube 4 mL of water and 1mL of chloroplast were added. In each of the other tubes, 1mL of phosphate buffer, 3mL of water, and 1mL of DPIP was added. DPIP was added to replace $NADP^+$ to observe the changes in transmittance. Each tube was then put into the cooler to preserve the chloroplasts until it was time to start the experiment.

After each tube was filled, tubes 1, 2, 3, and 4 (red, blue, green, white/control) were ready to be tested for 0 minutes. We set the spectrophotometer to 605 nm, though before putting any tube into the spectrophotometer, we would invert the tube with parafilm on top, to prevent contents from spilling, then wipe off the tube with a kim-wipe, to ensure no fingerprints or liquids were on the tube, since this could interfere with the photospectrometry readings for the rate of transmittance. The test tubes were inverted to make sure the contents are diluted and mixed well, so that chloroplasts are evenly throughout the solution. The calibration tube, which had no DPIP, was set in at 0 minutes to set the transmittance rate (%T) to 100%, meaning all light was transmitted through, and then each tube was quickly taken out of the cooler, where they had been stored and placed into the spectrophotometer, where the data was read, the tube was taken out, and then placed into a rack under lamp light for photosynthesis, this process was repeated for all four tubes. Under the goose-neck lamps, each tube, red, blue, green, and white had the same environment, in which a Erlenmeyer flask sat a heat sink to prevent the chloroplasts from overheating, across from the tube rack, which a single tube sat and absorbed the energy.

In this experiment our independent variable is a change in wavelength. The control for this experiment was white light. White light displays photosynthesis without the manipulation of wavelength. We expected to see photosynthesis occur under white light, establishing a baseline of what “normal” rates of photosynthesis read as.

We calculate the rate of photosynthesis by taking the change in transmittance rate over the change in time. Rate = (Change in %T)/(Change in time). We calculate the rate of photosynthesis to determine how much light is moving through the chloroplasts, and thus, how much the chloroplast photosynthesis. In this experiment the more that a chloroplast synthesizes, the greater the rate of photosynthesis will be, because the more photosynthesis that occurs, the more DPIP will turn from blue to colorless, and result in greater levels of light being transferred through the tube in the spectrophotometer.

## 3. RESULTS

We collected the transmittance rate of each tube at three-minute intervals, starting at minute 0. The initial readings were 18.70%, 18.90%, 19.00%, and 16.20% for the red, blue, green, and control tubes, respectively (Data Set 1). The control showed a significant increase in photosynthetic rate by the 3-minute mark, with a 10.10% increase, while the red, blue, and green wavelengths increased light transmittance by 6.00%, 5.60%, and 4.90%, respectively (Graph 1, Data Set 1).

At the 6-minute mark, the transmittance rates for the control and each variable were approximately 30%, indicating a continued increase in photosynthesis rates (Graph 1). The red wavelength increased by 6.30%, while the blue and green wavelengths increased by 3.70% and 5.10%, respectively. The control experienced a 5.20% increase (Data Set 1).

By the 9-minute mark, the peak transmittance rate was observed for the red wavelength at 38.30%, while the lowest rate was observed for the blue wavelength at 33.00%. The green wavelength and the control recorded transmittance rates of 35.30% and 37.00%, respectively (Data Set 1).

To determine the rate of photosynthesis over the nine-minute duration for each wavelength, we employed the equation (Change in %T)/(Change in Time). The resulting rates were 2.14%, 1.57%, 1.81%, and 2.31% for the red, blue, green wavelengths, and the control, respectively (Data Set 2).

These findings demonstrate the varying effects of different light wavelengths on the rate of photosynthesis, with red light showing a notably higher rate compared to blue and green light. Furthermore, our data suggest that white light, as represented by the control, may have a more significant impact on the rate of photosynthesis than previously expected. This information is crucial in understanding the optimal conditions for plant growth, particularly in controlled environments such as indoor farms, where light wavelengths can be manipulated to maximize growth rates and crop yields.

## 4. DISCUSSION

The present study sought to explore the effects of different light wavelengths on the rate of photosynthesis in spinach leaves. Our findings indicate that the photosynthetic rate under red light was significantly higher than that under green light, which supports our original hypothesis [10]. The results of this study are consistent with previous research demonstrating that the absorption of light by pigments such as chlorophyll a and b is wavelength-dependent and can influence the rate of photosynthesis [11].

It is noteworthy that the green chloroplasts in our experiment were expected to have a higher photosynthetic rate under red light, given that plants primarily absorb red and blue light due to the presence of chlorophyll a and b. However, our data suggest that under both red and green light, autotrophic organisms utilizing chloroplasts will exhibit optimal photosynthetic performance under red light. Interestingly, the highest photosynthetic rate was observed under the control condition, indicating that white light may be more effective than red or green light, or that there were potential errors in our experimental setup.

Despite our findings, limitations in our study may have affected the results. For example, factors such as fingerprints, water, or small smudges on the tubes may have affected the transmittance rates. Additionally, the red light bulb may have been less potent than the green and control bulbs, requiring replacement. Future experiments should consider the use of more robust controls and equipment to minimize potential confounding factors.

Our results have practical implications for agriculture, particularly in optimizing plant growth in indoor farming settings [12]. Our data suggest that green light should be avoided in favor of red light, while white light may be the most effective for promoting photosynthesis. This information can help increase plant growth rates in controlled environments by manipulating light wavelengths, ultimately improving crop yields and food production efficiency.

Further research should focus on comparing the effects of red, white, and other light wavelengths, such as blue light, on photosynthesis to determine the most effective wavelength for plant growth [13]. A deeper understanding of how different light wavelengths impact photosynthetic rates is essential for optimizing agricultural practices and promoting sustainable food production. Additionally, investigating the potential synergistic effects of different light wavelengths in combination may reveal new insights into plant physiology and adaptation mechanisms. Overall, this study provides valuable information for the optimization of plant growth in controlled environments and highlights the importance of light wavelength on photosynthetic rates.

## 5. CONCLUSION

In conclusion, our study demonstrated that the rate of photosynthesis is significantly affected by the light wavelengths to which plants are exposed. Our data revealed that red light is more effective at promoting photosynthesis than green light, while white light, as represented by the control group, might be the most efficient of all. These findings have important implications for agricultural practices, particularly in indoor farming, where manipulating light wavelengths can optimize plant growth rates and enhance crop production efficiency.

## 6. LIMITATIONS

Despite the valuable insights gained from our study, there were several limitations that may have influenced the results. Potential factors affecting the transmittance rates include fingerprints, water, or small smudges on the tubes. Moreover, the red light bulb might have been less potent than the green and control bulbs, which could have skewed the results.

To address these limitations and improve the reliability of our findings, future studies should employ more rigorous controls and well-maintained equipment. Additionally, a more extensive investigation of different light wavelengths, including blue light, should be conducted to better understand the optimal conditions for plant growth. This could involve exploring the potential synergistic effects of various light wavelengths in combination, which may provide further insights into plant physiology and adaptation mechanisms. By addressing these limitations, future research can continue to refine our understanding of the relationship between light wavelengths and photosynthetic rates, ultimately contributing to the development of more sustainable and efficient agricultural practices.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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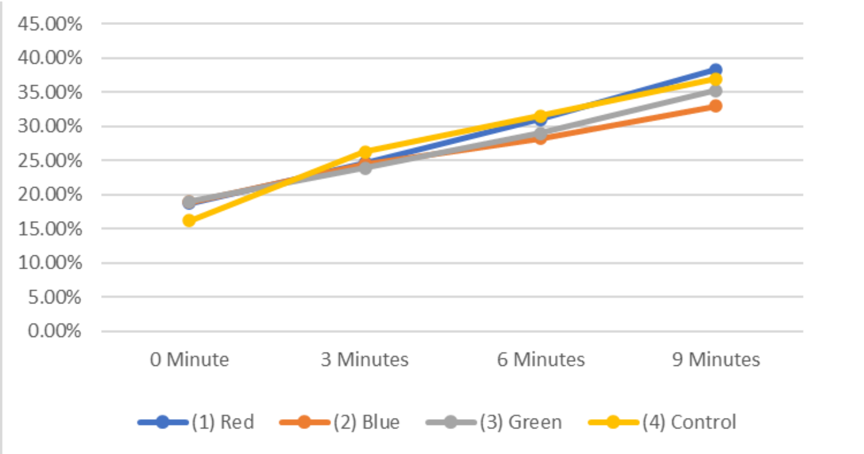
## APPENDIX

**Data Set 1. Light Transmittance over 9 minutes**

| | 0 Minute | 3 Minutes | 6 Minutes | 9 Minutes |
|---|---|---|---|---|
| (1) Red | 18.70% | 24.70% | 31.00% | 38.30% |
| (2) Blue | 18.90% | 24.50% | 28.20% | 33.00% |
| (3) Green | 19.00% | 23.90% | 29.00% | 35.30% |
| (4) Control | 16.20% | 26.30% | 31.50% | 37.00% |

**Data Set 2. Rate of Photosynthesis over 9 minutes**

| | Rate Of Photosynthesis |
|---|---|
| (1) Red | 2.14% |
| (2) Blue | 1.57% |
| (3) Green | 1.81% |
| (4) Control | 2.31% |




**Graph 1. Percentage value over the course of experiment**



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