The Effects of Colored LED Lights on Plant Height

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Abstract

The purpose of this experiment was to investigate the effects of the colored LED lights: white, blue, red, and yellow on the growth of green bean plants. Plants give oxygen that humans need to breathe, and are essential for economic growth, providing resources for many people. Climate change and seasonal changes aren't fully suitable for planting year round. The goal of this experiment was to support an efficient solution that would allow year-round planting using an indoor setting that tested the effects of colored LED lights on plant height. It was hypothesized that the green bean plants under the white light (control group) would end up being the highest compared to the other levels (blue, red, and yellow) because the sun regularly emits white light. The procedure started with the set-up of the experiment when the materials of lamps, lightbulbs, pots, soil, and seeds were placed on a table. There were 8 seeds and 3 pots for each light group, and over the course of 60 days, each plant received the same amount of water and length of time for light exposure. After three t-tests were conducted, the results were significant when comparing the mean height of the blue, red, and yellow light groups with the white light. The hypothesis that the white light is optimal was supported, and the other individual colored LED lights for the particular plants in this experiment at least, did not provide any benefit.

Keywords: colored LED lights, plant height

Introduction

Plants are an essential element of human life. They provide numerous benefits such as producing food, releasing the oxygen that we need to breathe, and are contributing components to many medicines. For example, planting is a big part of agriculture, as they are harvested and turned into crops to supply the surplus amount of food currently in the United States. They play a massive role in the economy. The United States Department of Agriculture (USDA) reports, "In 2019, there were 22.9 million full- and part-time jobs related to the agriculture and food sectors--10.9 percent of total U.S. employment. In addition to that, agriculture, food, and related industries contributed 1.109 trillion to the U.S. gross domestic product (GDP), a 5.2 percent share" (*USDA ERS - Ag and Food Sectors and the Economy*, 2020). Many economic sectors rely on agriculture, produced from plants including the food services, and eating and drinking places.

While plants have been beneficial to human society, there are a few factors that negatively affect the process of plant development. The problems are global climate change and the inability to conduct outdoor planting year-round. Climate change is the overall average long-term changes of the entire Earth. In recent years, the Earth's average temperature has been increasing due to various human activities, pollution, and greenhouse gas emissions. The greenhouse gas effect occurs when certain greenhouse gases, like carbon dioxide and methane, trap heat into the atmosphere that comes from the sun (National Geographic Society, 2012). Human activities include the burning of fossil fuels for coal, oil, and natural gas. "The U.S. Environmental Protection Agency reports that average temperatures in the U.S. have increased 0.14˚F per decade, and worldwide, the decade from 2001 to 2010 was the warmest on record since measurements began" (US EPA,OA, 2016). Inconsistent temperatures and the evolving climate affect the life cycle of plants, functioning ecosystems, and decrease in the plant's population in the coming years.

Most plants like cash crops cannot grow year-round because of the insufficient weather conditions and the environment. The planting season typically lasts for only a certain amount of time: Spring to Fall. Subsequently, there is a long duration of waiting time in the winter, where the weather is harsh, and the conditions are not ideal for a plant's growth. "Environmental factors that affect plant growth include light, temperature, water, and nutrition" (Cho, 2015). Without these factors, a plant cannot successfully survive and reproduce.

This project aims to answer the following research question: "Which colored LED light will affect a plant's growth the most?" The purpose of this project is to find an efficient and reliable solution to planting that can be done year-round. This project combats the challenges of today's world regarding climate change and the unreliability of planting year-round. The scientific hypothesis is the following claim: "If the green bean plants grow under the white light (control group), then they will end up being the highest compared to the other levels because the sun regularly emits white light." The plant growth will be the measurement of the height of green bean plants. There will be thirty two green bean plants in total, with eight plants each under the four different LED lights (white/control group, yellow, blue, and red) in the form of lightbulbs. This will be used to determine the effectiveness of indoor planting under a controlled environment. The experiment will be closely examined daily with the required, constant growth elements: light exposure, soil, and the amount of water given in order to collect the most adequate data.

Methodology

This project's primary focus was to determine which colored LED light affected a plant's height the most. This science experiment began by purchasing and acquiring the materials that were needed. For the planting component, 32 high-quality bush green bean seeds were purchased, and they grew in sandy, loam soil. The soil and seeds were kept in 12 separate plastic pots (7 inches deep and 7 inches in diameter) that were lightweight and durable. There was a plentiful supply of tap water that was used, where the seeds in each of the pots received the same amount of water poured from a measuring cup. Several cardboard pieces were applied under the pots to contain any spills or leaks and separate the experiment trials. Next, for the light component, four adjustable lamps were bought, along with the A19, non-dimmable, 60 watts, LED lightbulbs, with one used for the colors of white, blue, red, and yellow. Additionally, other materials were an outlet power strip, a ruler, and a table used to conduct the experiment, which took place indoors in the basement of a residential house.

For the plant set-up, sandy loam soil was used because it has the greatest impact on a green bean plant's growth with the even mixture of sand, silt, and clay. The soil was measured enough to where it was filled up in all 12 pots, which was approximately 7 inches deep. There are holes or openings at the bottom of the containers that allow water to drain, leaving space for the roots to spread. After filling the soil in the containers, a glove was worn for personal hygiene measures. Next, in each of the first 8 pots, 3 small holes were formed in the soil from the finger's insertion into the soil, with each hole being 2 inches apart and roughly 1 inch deep. The placement of the seeds in relation to the others is crucial because plants need space to grow. This process was repeated, except in the other remaining 4 pots; only 2 holes were formed in the soil with the same procedure as the previous description. Bush bean plants were used in this experiment because they were the most compatible with the indoor conditions. Moreover, 32 bush bean seeds were taken out of the purchased packet and were carefully placed in each hole. Then, the seeds were covered from the remaining soil that was out of place. There were 8 seeds under each of the 4 colored LED lights resulting in 2 pots with 3 seeds each and 1 pot with 2 seeds each.

In the light set-up, four adjustable lamps were brought and plugged into the outlet power strip to ensure that the lighting would be consistent throughout the experiment. Afterward, one LED lightbulb with each of the colors white, blue, red, and yellow was placed into the lamp socket by rotating them clockwise until they could not go in any further. To test if the lights would work, a small knob on the 3 of the lamps were twisted, while 1 lamp had a switch that was flipped, and all of the lights successfully turned on. For every day of experimentation, the plants received approximately 8 hours of light, since that is the amount of time that is optimal for a green bean plant's growth, in which enough warmth was provided. Next, the lamps were moved behind the plants and adjusted to ensure that all plants received the same amount of light. Each plant needed to have the same conditions because that resulted in collecting the most accurate data. The lightbulb and lamp were initially 12 inches above the plant in the beginning stages, but the height changed as the plant grew throughout the 2 month period.

Every day, 100 mL of purified water in a measuring cup was given to the plants in each pot. This specific amount of water was needed for a plant's maximum growth ability. Additionally, the water that was distributed to the plants depended on the soil's dryness. The dryness of the soil was determined by looking at the moisture levels. This was completed using a finger insertion, where a glove was worn, and a small hole of about 2 inches was created to view the soil moisture. When the soil was dry, lighter in shade, or less dark, that was the appropriate time to water the plants. When watering the plants, the water was poured gently onto the surface to make sure none of the components were damaged. It was crucial to use the right amount of water because if overwatering occurred, then the soil would be wet all of the time, limiting the amount of oxygen that the plant uses, damaging the system, and eventually dying. Like the effects of overwatering, underwatered plants become dryer and shrivel up as they lose an essential factor in their growth.

Over the past 2 months, the data was collected daily from observing the plants' growth. The growth was quantified by measuring the stem of the green bean plants using the height dimension. The measuring device was a 30 cm (centimeter) ruler that was utilized along with 1 mm (millimeter) intervals. These measurements determined which plants grew the highest under the different colored LED lights. A spreadsheet was created to store the collected data, which in turn was calculated and analyzed to conclude the results of the experiment. There were multiple tabs on the spreadsheet with the 4 colored LED lights white, blue, red, and yellow. In these tabs were the plant height for each of the trials, as well as the 8 parts in each category regarding the 8 plants under each light that were listed numerically from 1 to 8, as were the number of days (start to finish). Moreover, a scatter plot graph was created for each level, and all of the levels were combined using the data and was color-coded based on the color of the varying LED lights. Three statistical analyses (t-tests) were applied to show the significance of the collected data.

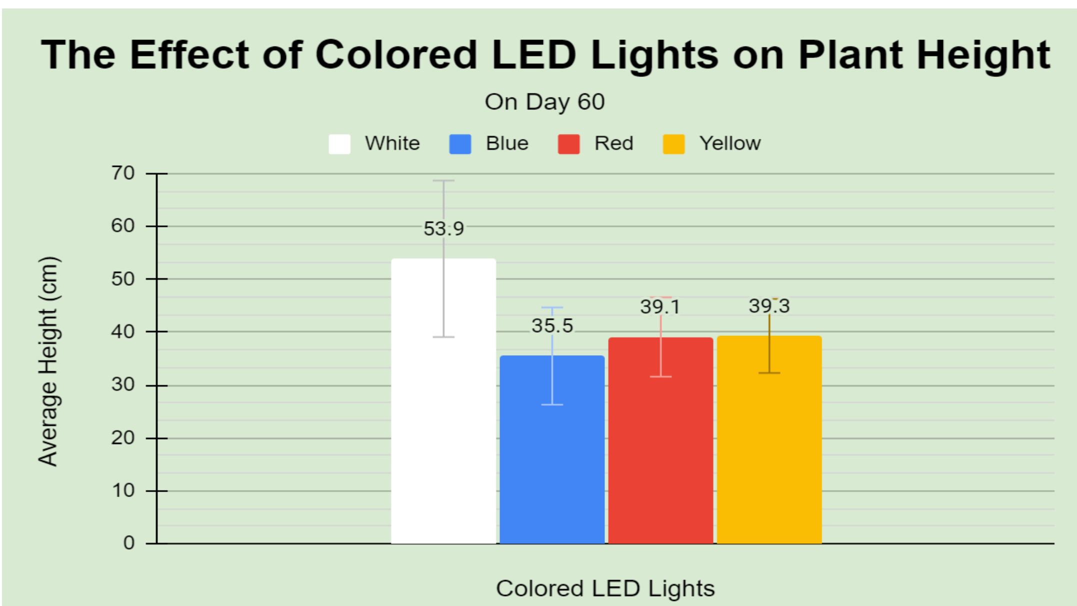
Data & Results

Table 1

Table 1: Height measured at the end of 60 days				
Height (cm)	Control (White Light)	Blue Light	Red Light	Yellow Light
Trial 1	52.6	46.4	33.4	39.8
Trial 2	60.3	24.4	44.5	37.6
Trial 3	65	***		31.4
Trial 4	58.8	42.3	30.2	48.3
Trial 5	60	***	41.6	***
Trial 6	67.4	36.4	50	***
Trial 7	21.5	38.8		***
Trial 8	45.2	24.6	35.1	***

*** Never Sprouted/System Failure

Figure 1

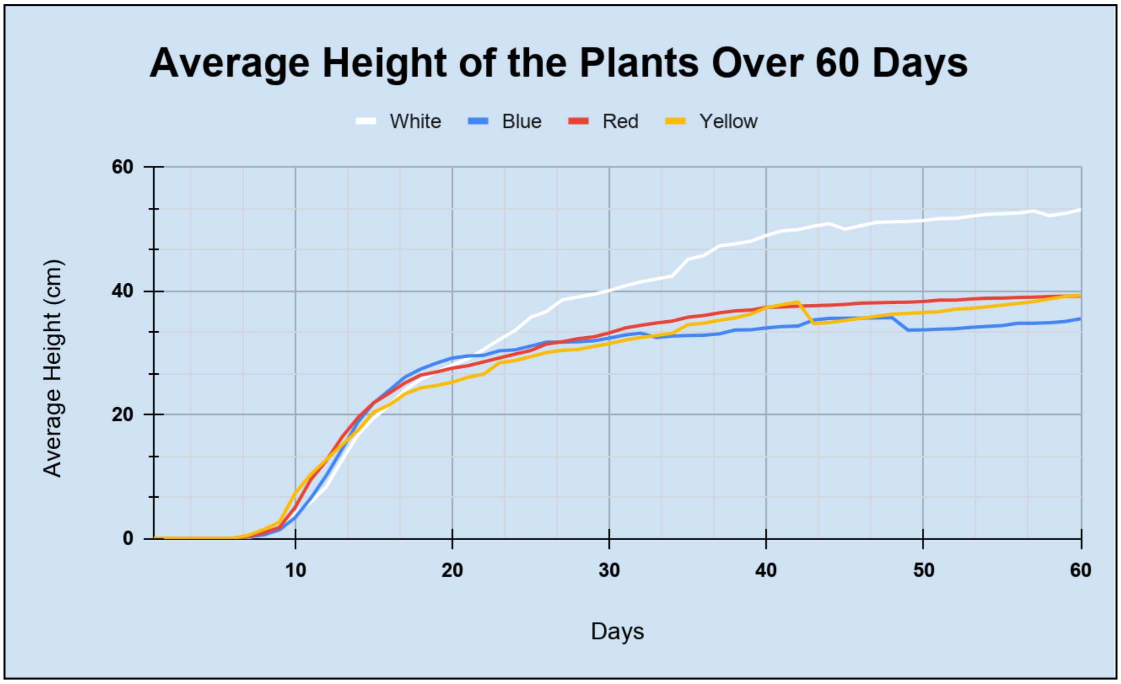


The average height of the plants under each of the colored LED lights at the end of 60 days is shown above in Table 1 and graphically represented in Figure 1. The mean height of the control group was significantly higher than all of the other LED light levels. The blue light level was the lowest of the 4, while the red and yellow light levels were relatively similar to each other. In 3 of the 4 levels, there were trials or plants that weren't included in the table and graph due to reasons such as the inability of certain seeds to sprout, and two plants' heights decreased from a system failure during the 60 days of experimentation. Therefore, those trials couldn't be included in the data because of the varying level of accuracy. This data supports the research hypothesis that the white light plants will be higher than the other light levels.

Table 2

Table 2: Effect of Different Colored LED Lights on Plant Growth				
Colored Lights	**White**	**Blue**	**Red**	**Yellow**
Mean	**53.9**	**35.5**	**39.1**	**39.3**
Standard Deviation	**14.8**	**9.2**	**7.5**	**7**
1 SD (68% Band)	**39.1 - 68.7**	**26.3 - 44.7**	**31.6 - 46.6**	**32.3 - 46.3**
2 SD (95% Band)	**24.3 - 83.5**	**17.1 - 53.9**	**24.1 - 54.1**	**25.3 - 53.3**
3 SD (99% Band)	**9.8 - 98.3**	**7.9 - 63.1**	**16.6 - 61.6**	**18.3 - 60.3**
Results of t-test		**t = 2.66543, p = 0.010292**	**t = 2.21472, p = 0.023441**	**t = 1.83556, p = 0.048148**
For all:	**significant**			
Degrees of Freedom:	**7**	**5**	**5**	**3**
Alpha = 0.05				

Figure 2



The height of the plants under each colored LED light at the end of 60 days is presented in Table 1. The effect of colored LED lights (white, blue, red, and yellow) on the average height of the green bean plants are summarized in Figure 1 and graphically represented over the course of this experiment in Figure 2. As indicated in Table 2, the plants under the blue light had a significantly lower mean height (35.5 cm) than the control group (53.9 cm). The standard deviation of the blue light plants were 9.2, while the control group standard deviation was 14.8. Like the blue light plants, the red and yellow light plants also exhibited a lower mean height than the control group (39.1 cm, and 39.3 cm). The variations of the red and yellow light plants were similar, with the standard deviations of 7.5 and 7. A one-tailed, uncorrelated, unequal sample t-test was used to test the following null hypothesis at the 0.05 level of significance: the mean height of the plants under the blue light is not significantly different than the mean of the plants under the control (white light). The same null hypotheses were used for the red and yellow light levels. For the blue light, $t(6) = 2.66543$, and $p = 0.010292$, the red light with $t(6) = 2.21472$, and $p = 0.023441$, and the yellow light with $t(4) = 1.83556$, and $p = 0.048148$. The alternative hypotheses were not rejected, and the research hypothesis, the white light plants will be higher than the plants under the other lights, was supported.

Conclusion

The purpose of this experiment was to investigate the effects of the colored LED lights white, blue, red, and yellow on the growth of green bean plants. The goal also was to find an efficient and reliable solution to planting that can be done year-round. The experiment was maintained throughout a 60 day period where each plant was treated with the same conditions indoors, which were the length of time for light exposure, and the amount of water that was provided each day. This experiment's findings are best used to provide an understanding of the colored light that is best for the maximum potential growth of plants through consistently measuring their height.

This project was successful at supporting an efficient solution to year-round planting, through the use of indoor planting. At the end of the experimentation period, which was over the course of 60 days, the mean height of the control group (white light) was the highest compared to the other levels with 53.9 cm. The mean height of the plants under the blue light was the lowest at 35.5 cm. The red and yellow lights had similar results, with the red light at 39.1 cm, and the yellow light at 39.3 cm. As supported by the data, the mean height of the white light plants was significantly higher than the other LED light groups.

The data supported the hypothesis that the green bean plants under the white light (control group) would end up being the highest out of all the levels because the sun regularly emits white light. Moreover, the data was statistically significant for all of the independent variable levels from the three t-tests that were conducted with the mean of the blue light plants ($t = 2.66543$, $p = 0.010292$), the red light plants ($t = 2.21472$, $p = 0.023441$), and yellow light plants ($t = 1.83556$, $p = 0.048148$). In each of these t-tests, the null hypothesis was rejected and the alternative hypothesis was not rejected.

The results of the experiment concluded with the white LED light having the greatest impact in supporting the plants with the highest mean height. This is due to light in general, which is a very important factor for plants' growth. Light helps plants go through photosynthesis, a process that turns sunlight into chemical energy that is used to make energy. This helps plants grow and reproduce. The color of the light also plays a key role in the growth and eventual height of plants. Plants use all colors and that is exactly what white light provides. Because it provides all colors, and because it is the light that plants receive out in nature, white light is the best light for plants (*How Does White Light Affect Plant Growth? - Grow Light Info*, 2020). A source of error were two trials/plants that weren't included because there was a system error, and an additional 6 plants weren't considered as part of the experiment because they never sprouted. This affects the overall data because it resulted in a smaller group of trials.

Further studies on the effects of colored LED lights on plant growth should include additional wavelengths of light (color) to expand the findings for more results. The experiment can have lighter and darker shades of the specific colored light. Doing this would require a certain extent of knowledge about the visible light spectrum, along with the range of numbers (nanometers as the unit) for each light color. This could identify the types of shade in each color that are more impactful to the plant's height. Another extension could be different wavelengths of light being used on plants at set amounts of time during the plants' growth. Using combinations of these lights can compare the varying colors and their effects on a plant's maximum growth. Further experimentation should include extra trials or plants in groups of 20-30 seeds. This will further increase the accuracy of the data since there are more trials. After reviewing the methodology, this experiment could be improved by having a larger set-up, possibly with more space to put the pots and lamps. Having one more lamp with a lightbulb for each level would evenly distribute the amount of light exposure that each plant receives. This can be done by having two or more lamps, depending on the number of trials, at opposite ends.

Appendix

https://docs.google.com/spreadsheets/d/127NBySbY9aPiTYAL23XesAsdEaArATwaK1oUaAukl4o/edit?usp=sharing

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