Plant Growth as a Function of LED Lights

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Abstract: In most lab settings the Brassica Rapa plant can be efficiently grown under a 32-watt fluorescent light bulb. In this experiment a group of 16 controlled Brassica Rapa plants were set under a fluorescent light guided by the following procedures of the Wisconsin Fast Plant Guide, and another set of 16 plants set under a 12-watt LED light. Both groups were under the same conditions during germination. However, the rate at which they germinated was not the same. The overall growth was determined that the LED experimental plants had a higher increased growth rate compared to the fluorescent plant group.

Introduction:

Light is an essential product in plant growth and development. As producers in most ecosystems, plants rely heavily on some sort of light source. T````````he presence of light plays a major role in plant morphology. Plants respond to the quality, quantity, and direction of light. Light is required in photosynthesis, a plant's process of creating food and energy.[1] The sun is the greatest light source for outdoor plants. However, substitute lighting can support the growth of plants indoors. Fluorescent light bulbs provide nearly all the benefits of sunlight. Most importantly, they produce the wavelengths of light that a plant needs to grow. In fluorescent light bulbs, mercury vapor emits ultraviolet light. The light excites the tri-phosphors of red, green, and blue on the inside of the glass, which in turn produces white light.[2]

Currently, the use of fluorescent light bulbs is being evaluated. Botanists are questioning whether or not other lighting systems can facilitate the growth of indoor plants. Promising ideas of energy efficient light sources are being sought after. Fluorescent lights are slowly being replaced by new, more energy efficient light bulbs- LED lights. LEDs are light-emitting diodes, which means that they convert electricity into light by using properties of metals to generate photons. The white light that is produced by an LED light actually comes from the emission of blue wavelengths. The blue wavelengths hit a phosphor coating on the glass of the bulb that emits yellow wavelengths of light. The combination of the yellow and the blue wavelengths give off white light.[3]

Plants have light receptors that detect visible light and generate a response. Through experimentation, scientists have concluded that red light and blue light have the greatest effects on plant growth. Blue-light photoreceptors absorb wavelengths of blue light and trigger a number of reactions in plants. Blue wavelengths affect phototropism, the opening of stomata (which regulates a plant's retention of water), and chlorophyll production. Phytochromes absorb mostly red light. Red wavelengths set off a variety of responses in plants as well. They initiate seed germination and root development, and regulate shade avoidance. As an example, scientists from the U.S. Department of Agriculture tested the germination of lettuce seeds under red light.

[1] Jane B. Reece and Neil A. Campbell. Biology: 9th Edition. (California: Pearson Education, 2011), 835.

[2] Apollo Lighting & Supply Co. (2008). *All About Light Bulbs.* Accessed on October 3, 2011. http://www.mass-lighting.com/lightbulbs.html

[3] Siddha Pimputkar et al. *Nature Photonics: Prospects for LED Lighting*. Volume 3: April 2009. Accessed October 1, 2011. http://lib.semi.ac.cn:8080/download/2009/04/22/093823.pdf

They determined that red light increased the germination percentage of the lettuce seeds.[4]

Because fluorescent lights produce the red wavelengths of light necessary for seed germination, the *Brassica rapa* seeds were germinated under the fluorescent light. Once the seeds had germinated, half of the plants were moved under the LED light. The LED light emitted the blue wavelengths of light required for plant growth.

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[4] Jane B. Reece and Neil A. Campbell. Biology: 9th Edition.(California: Pearson Education, 2011), 836.

Methods:

Brassica rapa is an ideal specimen for experiments. Its growth cycle can be carried out within 40 days, which offers scientists quick results. The plants were tested for growth under two different light sources, fluorescent light versus LED light. This experiment aimed to discover whether or not LED lights produce the necessary wavelengths of light needed in plant growth using less amount of energy than . It was predicted that LED lights can be used as an effective substitute for florescent light bulbs when growing plants. Plants will produce similar growth results under LEDs as they do under fluorescent lights.

Both the control group (fluorescent) and the experimental group (LED) were set up following the fast plants instruction guide.[5] Both groups were allowed to germinate under the same conditions, under the fluorescent light. A 32-watt fluorescent light bulb was used, which radiates 2900 lumens.

After the first seven days, germination was evident, and the experimental group was moved into an isolated lighting box setup. There, it was placed solely under an LED light. A Phillips Ambient LED 12-watt A19 light bulb was used. This bulb radiates 800 lumens. The amount of lumens is determined by the light source, not by the physical size of the bulb.[6]

In order to provide the plants with equivalent lighting, each week the distance of the LED bulb from the plants had to be adjusted. The distance was determined by calculating the lux value for the control group. Then an equal lux value had to be calculated for the experimental group. Lux measures the amount of lumens per square unit. **Table 1** shows the weekly lux calculations for both groups. The following formula was used:

$$\frac{\textbf{Lumen Output}}{\textbf{(Distance of light - Average height of plants)}^2}$$

The plants were watered and pollinated according to the treatment in the fast plants instruction guide. Each week, measurements were recorded of the total height of the plants and the width of their foliage. The presence or absence of cotyledons was also noted. Pictures of both groups were taken as well.

Table 1: Lux Calculations

Week	Fluorescent	LED
1	$\frac{2900\text{ lumens}}{(25cm-3.46cm)^2}$ = **6.25**	$\frac{800\text{ lumens}}{(18cm-6.67cm)^2}$ = **6.23**
2	$\frac{2900\text{ lumens}}{(33cm-4.32cm)^2}$ = **3.53**	$\frac{800\text{ lumens}}{(27cm-12.1cm)^2}$ = **3.60**
3	$\frac{2900\text{ lumens}}{(33cm-5.5cm)^2}$ = **3.83**	$\frac{800\text{ lumens}}{(28cm-13.5cm)^2}$ = **3.80**
4	$\frac{2900\text{ lumens}}{(33cm-7.11cm)^2}$ = **4.33**	$\frac{800\text{ lumens}}{(28.5cm-14.7cm)^2}$ = **4.20**
5	$\frac{2900\text{ lumens}}{(33cm-8.82cm)^2}$ = **4.96**	$\frac{800\text{ lumens}}{(29cm-16.1cm)^2}$ = **4.81**

[5] D. Lauffer and P. Williams. (2007). *Wisconsin Fast Plants*®. Accessed on October 1-November 30, 2011. Wisconsin Fast Plants Web site: www.fastplants.org

[6] Apollo Lighting & Supply Co. (2008). *All About Light Bulbs.* Accessed on October 3, 2011. http://www.mass-lighting.com/lightbulbs.html

Results:

Both groups were under the same conditions during germination. However, the rate at which they germinated was not the same. The experimental group(LED) experienced far greater growth within the first seven days than the control group(fluorescent). Therefore, the final growth of the plants was compared to the initial differences that emerged during germination.

The average height of the control plants showed a growth from 3.46cm to 8.82cm, indicating an overall growth of 5.36cm. The average height of the LED plants showed a growth from 6.67cm to 16.1cm, indicating an overall growth of 9.43cm. In terms of plant height, the LED light produced 56.8% greater growth than the fluorescent light. **Table 2** compares the average height of both groups.

The average width of the foliage in the fluorescent plants showed a growth from 1.01cm to 2.16cm. This indicates an overall growth of 1.15cm. The average width of the foliage in the fluorescent plants showed a growth from 2.3cm to 3.98cm. This indicates an overall growth of 1.68cm. In terms of plant width, the plants grown under the LED light produced 68.5% greater growth than the plants grown under the fluorescent light. **Table 3** compares the average width of the foliage in both groups.

All the plants that germinated produced cotyledons during their growth cycle. This suggests that both light sources had the same effect on the emergence of cotyledons.

Graph 1 shows the rate of growth (height and width) of both groups over the experimental period.

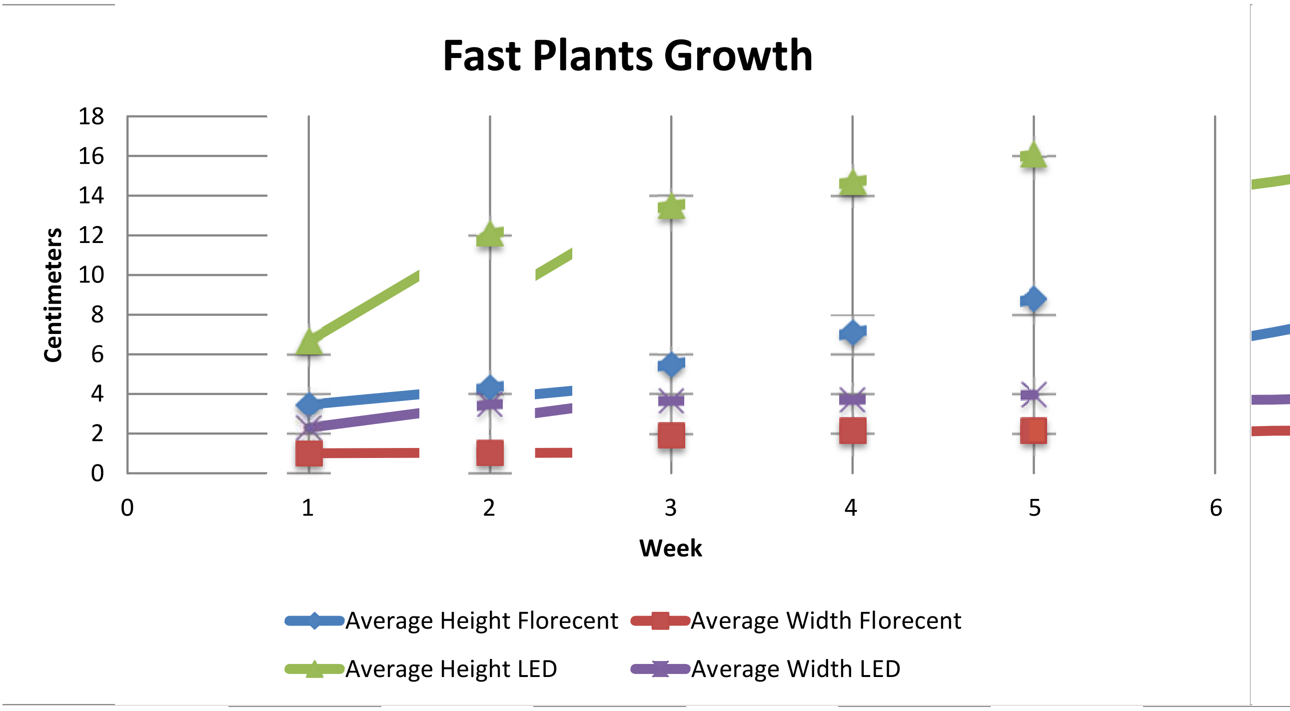
Table 2: Average Height

	Average Initial Height	Average Final Height	Overall Growth in Height (final-initial)
Fluorescent	3.46cm	8.82cm	5.36cm
LED	6.67cm	16.1cm	9.43cm

Table 3: Average Width of Foliage

	Average Initial Width	Average Final Width	Overall Growth in Width (final-initial)
Fluorescent	1.01cm	2.16cm	1.15cm
LED	2.3cm	3.98cm	1.68cm

Graph 1: Rate of Growth



Calculations/ Error Analysis

A T test was calculated in order to determine the difference in florescent height/ width compared to LED height/ width.

T test Height LED:

P **cm**	T **cm**	Df **cm**	Standard Error Difference **cm**	Mean **cm**	Standard Deviation **cm**	# of Values
0.0072	3.5824	8	1.890	12.6140	3.6361	5

T test Width LED:

P **cm**	T **cm**	Df **cm**	Standard Error Difference **cm**	Mean **cm**	Standard Deviation **cm**	# of Values
0.0019	4.5311	8	0.392	3.4320	0.6558	5

T test Height Florescent:

P **cm**	T **cm**	Df **cm**	Standard Error Difference **cm**	Mean **cm**	Standard Deviation **cm**	# of Values
0.0072	3.5824	8	1.890	5.8420	2.1554	5

T test Width Florescent:

P **cm**	T **cm**	Df **cm**	Standard Error Difference **cm**	Mean **cm**	Standard Deviation **cm**	# of Values **cm**
0.0019	4.5311	8	0.392	1.6540	0.5829	5

Discussion:

This experiment makes it evident that plants grown under LED lights experience far greater growth than plants grown under fluorescent lights. A number of environmental factors could explain the differences between the two groups. During germination, the plants were treated under the same conditions, yet the LED group grew twice as much as the fluorescent group within this first week. This initial variation among the two groups could have affected the entire cycle of growth that followed. Also, the LED plants were isolated in a lighting box setup. The temperature produced by the LED light within that box was unknown. Therefore, there is no data analyzing the effects that may arise due to differences in heat output among LED and fluorescent light bulbs.

Data analysis concludes that LED lights produce the necessary wavelengths of light needed in plant growth. The plants grown under LED lights produced growth that exceeded that of the plants grown under fluorescent lights. This concludes that LED lights can be used as an effective substitute for florescent light bulbs when growing plants indoors. Because LEDs use less energy, they are more resourceful and environmentally friendly. Ecologically, they provide a better replacement for the fluorescent bulb as well.

This was a successful experiment. The experimental design followed along the lines of a reasonable and testable hypothesis. For future experiments, it would be beneficial for both groups of plants to have the same, or nearly the same, germination rate before isolating the experimental LED group from the control fluorescent group. This will provide an easier way of determining which group of plants had the most overall growth. It is also imperative to investigate the differences in temperature produced by fluorescent light bulbs and LED light bulbs. This information will provide greater insight of the data analysis for this experiment.

References:

Apollo Lighting & Supply Co. (2008). *All About Light Bulbs.* Accessed on October 3, 2011. http://www.mass-lighting.com/lightbulbs.html

Jane B. Reece and Neil A. Campbell. Biology: 9th Edition. California: Pearson Education, 2011.

Siddha Pimputkar et al. *Nature Photonics: Prospects for LED Lighting*. Volume 3: April 2009. Accessed October 1, 2011. http://lib.semi.ac.cn:8080/download/2009/04/22/093823.pdf

D. Lauffer and P. Williams. (2007). *Wisconsin Fast Plants®*. Accessed on October 1-November 30, 2011. Wisconsin Fast Plants Web site: www.fastplants.org