TED ANKARA COLLAGE

FOUNDATION PRIVATE HIGH SCHOOL

ENVIRONMENTAL SYSTEMS AND SOCITIES

FULL INVESTIGATION

INVESTIGATING THE EFFECT OF THE CHANGE IN WAVELENGTHS OF LIGHT ON THE GERMINATION RATE OF *Lactuca Sativa*

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[1]: http://en.wikipedia.org/wiki/Germination
[2]: http://www.highmowingseeds.com/sb-factors-affecting-germination-of-organic-seeds.html
[3]: http://bioted.tedankara.k12.tr/lnotes.php
[4]: http://en.wikipedia.org/wiki/Germination#Dormancy
[5]: http://science-edu.larc.nasa.gov/EDDOCS/Wavelengths_for_Colors.html

ABSTRATCT

The main idea of this extended essay is to investigate the rate of germination of the specialized seeds *(Lactuca Sativa)* with the change of wavelength of the light. My research question is “How does different wavelengths of light affect the rate of germination as measured by observing number of sucessfully germinated seed of Lactuca Sativa under the influence of the same temperature, volume of water, time of enlightening ?” and my hypothesis for this extended essay is ” It can therefore be hypothesized that as we increase the wavelength of the light germination rate of Lactuca Sativa will be increase.” With these ideas I have planned and designed my own method in order to answer my research question and prove my hypothesis. While doing this experiment I have used a germination pot, led lights and lettuce seeds. The setup was planned as; each trial poured with water at first day(30ml) and the fifth day(10ml). Also in order to decrease the errors I have used same brands seeds because it decreases the variety between each seed. I put 50 seeds to each trial and enlightened them with different wavelengths of light; red, green, yellow, blue, violet. At the end of collection of datas I compared them with each other, however I have seen that, an error occurred during the germination process of seeds. If we compare the data ignoring the errors caused by several external factors, I can conclude that as the wavelength of light increases germination rate will increase. Moreover, according to ANOVA test there was a significant mean difference between the number of germinated seeds. I have used lettuce seeds because these seeds are photo dormant seeds and I can obtain observable results.

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Introduction:

In this experiment, my aim is to observe the effect of change in the wavelength on the germination of the seeds of lettuce.

Background Information:

In this investigation, germination of lettuces is observed. Plants have four important processes throughout their lives such as photosynthesis, fertilization, maturation and germination. This report is about the process of germination.

Simply, "Germination is the process by which a plant grows from a seed."[1] If conditions are suitable for seed to emerge from the seed, it germinates to form a seedling.

"When the right environmental cues wake the seeds up they begin to germinate and emerge from their hard seed coat."[2] There are four major factors that are affect germination; water, temperature, oxygen and light. If these factors doesn't sustained seeds doesn't germinate and wait until the favorable conditions are ensured.

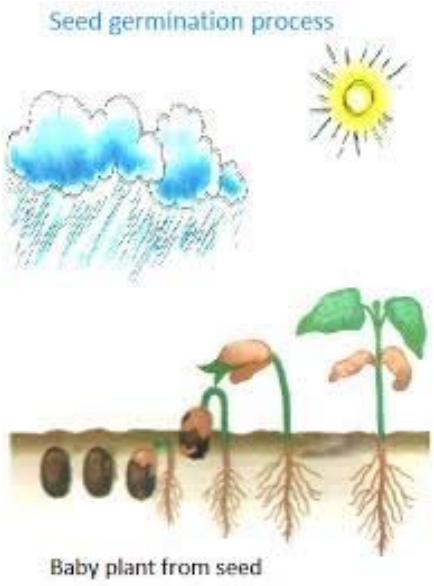

Figure 1. shows the process of seed germination.

Firstly I am going to talk about the effect of water, humidity to the germination of seeds. Seeds are dry when we put it to the soil. So it needs to take water inside its shell. By the time water enters in seed, it activates the enzymes and hormones like gibberellins " which was stimulates and promotes germination, promotes growth through cell elongation"[3] and also to hydrolysis of endosperm which is a food source of seed. With the hydrolysis of

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endosperm, food given to the seed with the help of cotyledons and seed starts to produce energy with the decomposition of nutrients. As a results most of the seed will swell.

Temperature has an important role in germination because it also affects the diffusion and enzyme activity and it affects also to the growth rates. Optimum temperature for each seed differs from each other.

Also oxygen effects the germination rate because oxygen used in the aerobic respiration as a main source of energy to the seed until it makes photosynthesis.

Lastly "light and darkness can be an environmental trigger for germination and is a type of physiological dormancy. Most seeds are not affected by light or darkness, but many seeds, including species found in forest settings, will not germinate until an opening in the canopy allows sufficient light for growth of the seedling."[4]

If these factors doesn't sustained to seed to germinate, they maintain their lives under a period called "dormancy". This period can be occurred because of several unfavorable conditions and it can last for a week, for a month or maybe for years. In this period there is no growth occurs. As a result by the time the conditions ensured, plant starts to geminate and dry weight decreases as time passes until plant starts to make photosynthesis and produce its own food.

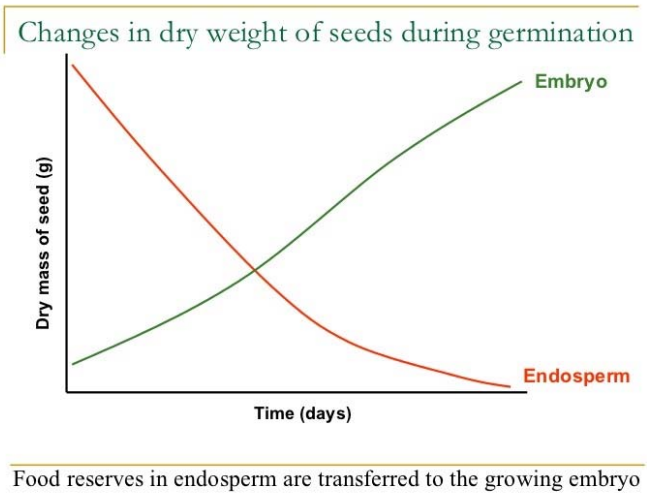

Figure 2. The graph of dry mass versus time during the process of germination.

In this investigation, in order to observe the effects of different wavelengths on germination I have used three different wavelengths; red, blue and green.

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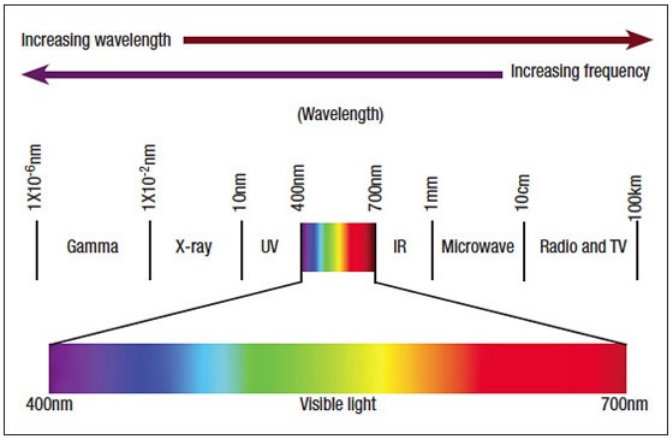

Figure 3. The figure of wavelengths

Wavelengths Of Light[5]:

- Red light has a wavelength about 650 nanometer(nm).
- Yellow light has a wavelength about 570 nm.
- Green light has a wavelength about 510 nm.
- Blue light has a wavelength about 475 nm.
- Violet light has a wavelength about 400 nm.

Lactuca Sativa:

Lettuce has a big green leaves, it is an annual, moderate climate vegetable. Its optimum temperature to live is 24C°. The reason why I have selected lettuce is because of it is a photodormancy and thermodormancy plant.

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Research Question

How does different wavelengths of light affect the rate of germination as measured by observing number of sucessfully germinated seed of Lactuca Sativa under the influence of the same temperature, volume of water, time of enlightening ?

Variables

Dependent variable: Rate of germination of *Lactuca Sativa*

Independent variable: Wavelengths of the lights;

Red light has a wavelength about 650 nanometer(nm).

Yellow light has a wavelength about 570 nm.

Green light has a wavelength about 510 nm.

Blue light has a wavelength about 475 nm.

Violet light has a wavelength about 400 nm.

Hypothesis

As light and darkness can be a environmental trigger for some of the seedlings, light has an impact on the germination of seeds for some type of plants which can be said to be as physiological dormancy. Generally germination of seeds is not affected by the light, however I am going to use lettuce seeds which was a type of photo dormant seed.

As different wavelength of light different energy I thought that each wavelength has an special impact on rate of germination. From the things that I have learned from my research. I found that as we increase the wavelength of the light germination rate will be increase.

It can therefore be hypothesized that as we increase the wavelength of the light germination rate of Lactuca Sativa will be increase.

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Method Developement And Planning

The planned investigation has a main point of determining the best wavelength of light for lettuce seed to germinate. In order to reduce the some of the possible error that can be occured from seeds I bought them at the same time and save them at a cold and drought place in order to prevent the possible germination at seed pocket. After gathering some information from internet by reading past experiment which was closed to mine. Then I have decided that the best possible plant that I can use in this investigation is *Lactic Sativa*, lettuce plant, which has a photo dormant seeds.

Another side of *Lactic Sativa* is that it can be germinate at nearly 8 days. It is such a great advantage for me because as the time of the experiment increases some of the errors that can be occurred by myself is also increase. Also I don't really have a time at school time so I have determine a date which was at semester break, and this experiment must be fit in these 15 days. Also optimum temperature for lettuce seeds to germinate is calculated as 24°C which was nearly at room temperature so that it eases the conditions of the experiment.

I have made my experiment at my house which was not a good place to make an experiment because it is hard to control some of the variables at house conditions such as calculating the humidity and stabilize the temperature. In order to control the humidity I have used a vapor machine which keeps medium moist. Also in order to control the temperature I have bought a controller to heating system at my house, by that way I can stabilize the temperature to 24°C. Also there were other variables that I also need to control to make my experiment more reliable and the table of these variables are shown below;

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Controlled Variables	Method Of Controlling
Type of seed used In experiment	In each trial I have used *Lactuca sativa*
Number of seeds used in each trial	In each trial I have used 50 seeds to each division
Size of parts that I have put the seeds	Each has 11 cm length and 14 cm width
Types of cotton used In experiment	I always used the same brands cotton
Volume of water used	First day I have 30ml water then in the fifth day I have added 10 ml water to each trial.
Number of days that they stay	8 days
Insolation times	Each stayed under light 80 hours
Temperature of the water used	Each water has a temperature of 18C°
Temperature of the environment	Every trial stayed at the same room at an average temperature of 24C°
Distance between light source and seeds	Cover of the germination pot, put with same length.

Table 1. The variables needed to kept constant and the method of keeping constant.

These variables had to be kept constant in order to take sustainable and observable results. Also this would increase the accuracy of the data later to be collected.

I have decided to use four different wavelength of light; Red light 650 nm, yellow light 570, green light 510nm, blue light 475 nm and 450nm violet . I am going to make my last trial with no light in order to see to what extent can light affects the germination rate of lettuce seeds. From these independent variables I am going to make my experiment from 5 trials.

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Obtaining the lights with different wavelength is hard to find because, all lights are in the form of bulb however bulb is not a good material for this experiment because it is hard to set up electric circuit which passes from the upper side of the seeds and most of the seeds wouldn't get the light with the same quantity. Accidentally, while I was searching about other materials I have found a led light which is in the form of stripes. Which helps me to distribute light equally.

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Method

Materials and Apparatus:

- 750 seeds of lettuce
- 600mL of water
- 3 new box of cotton
- 1 syringe
- 1 room thermometer
- 1 towel
- 1 coat
- Germination pot
- 4 stripes of led light each with different colors and with the length of 40 cm long and 8,8 W
- Strips
- 1 controller for temperature

Firstly 55cm long germination pot obtained and then divided to 5 equal parts with putting some cardboards with the width of 14 cm and the height of 6cm between each division by that way length of each division said to be as 11cm long. Cottons of the same brand with the same length and width placed to these equal divisions, it is important to cover all the surface with cotton because it can lead us some fallacies in the condition of some of the seeds may drop to the surface and we cannot observe any result for these seeds. Then transparent cover of the germination pot taken and led lights fixed inside the cover wit the help of band. While I

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was setting the lights I show attention to fix those lights with 2.5 cm apart from each other because the width of the cover is 11.5cm so that each division gets the light with the same quantity. 50 seeds of lettuce plotted to the each part of the germination pot. 30ml of water at 18C° poured to each division. Top of the germination pot covered with the cover that was just fixed led lights on it , room thermometer placed to the top of the cover and then whole system being covered by towel in order to prevent the affect of external light on the system. Then lights get opened. Opening process of the lights starts at 08:00 at morning and lights closed at 18:00 at afternoon. Before opening the lights at morning and after closing the light at afternoon temperature checked with the room temperature and average temperature calculated and this process repeated each day. On the 5th day 10ml more water poured to each division. It is important to pure the water with no light because while pouring water you have to open the cover of the germination pot so that system can directly get light from environment. After 3 more days seedlings that were successfully germinated counted and I have note the results to my notebook. These process is repeated for four more times with different wavelength of light.

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Figure 4. Putting the cottons to the 11cm divided parts.

Figure 5. Testing the lights and being sure that lights don't fall down during 8 days.

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Figure 6. Putting 50 lettuce seeds to the each divided parts.

Figure 7. Closing the transparent cover of the pot with the help of towel.

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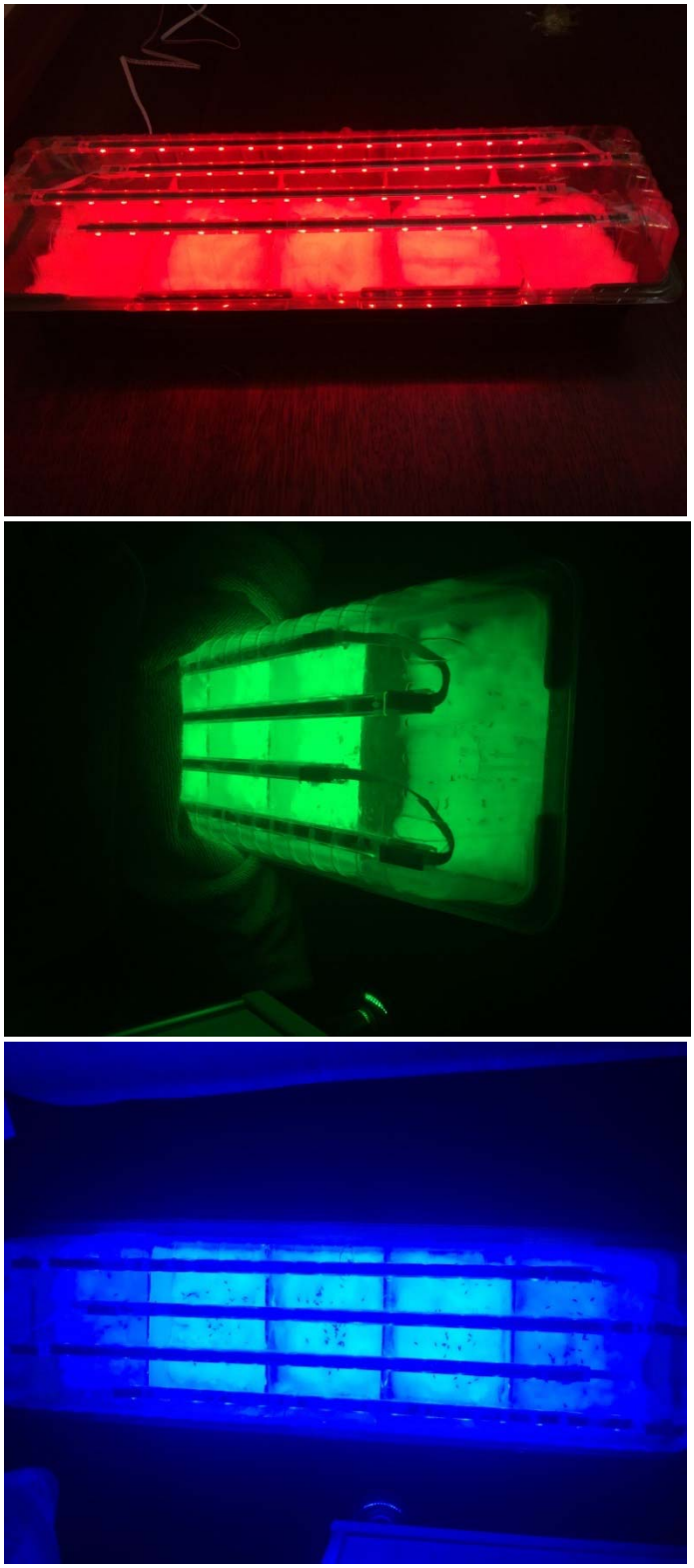

Figure 8. Opening the lights.

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Results and Data Analysis

Raw Data Table:

Colours of lights	Trials	Area Of The Parts(± 2m²)	Volume Of Water (ml ± 0.5)	Temperature (± 0.5 C°)	Number Of Seeds	Number Of Germinated Seeds
Red	1	154	40,0	24	50	50
	2	154	40,0	24	50	23
	3	154	40,0	24	50	11
	4	154	40.0	24	50	40
	5	154	40,0	24	50	48
Yellow	1	154	40,0	24	50	38
	2	154	40,0	24	50	40
	3	154	40,0	24	50	36
	4	154	40,0	24	50	40
	5	154	40,0	24	50	39
Green	1	154	40,0	24	50	31
	2	154	40,0	24	50	33
	3	154	40,0	24	50	38
	4	154	40,0	24	50	37
	5	154	40,0	24	50	42
Blue	1	154	40,0	24	50	40
	2	154	40,0	24	50	37
	3	154	40,0	24	50	34
	4	154	40,0	24	50	38
	5	154	40,0	24	50	39
Violet	1	154	40,0	24	50	37
	2	154	40,0	24	50	35

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	3	154	40,0	24	50	32
	4	154	40.0	24	50	34
	5	154	40,0	24	50	35

Table 2. Raw data table of percentage number of seeds germinated with the same size, volume of water and with the same number of seeds in each part with different wavelengths at a certain time.

Processed Data:

Sample Calculations

While I was calculating the mean number of germinated seeds I used the formula of calculating arithmetic mean;

Divide

$$\frac{X_1+X_2+X_3+X_4+X_5}{5}$$,where x values are the counted germinated seeds.

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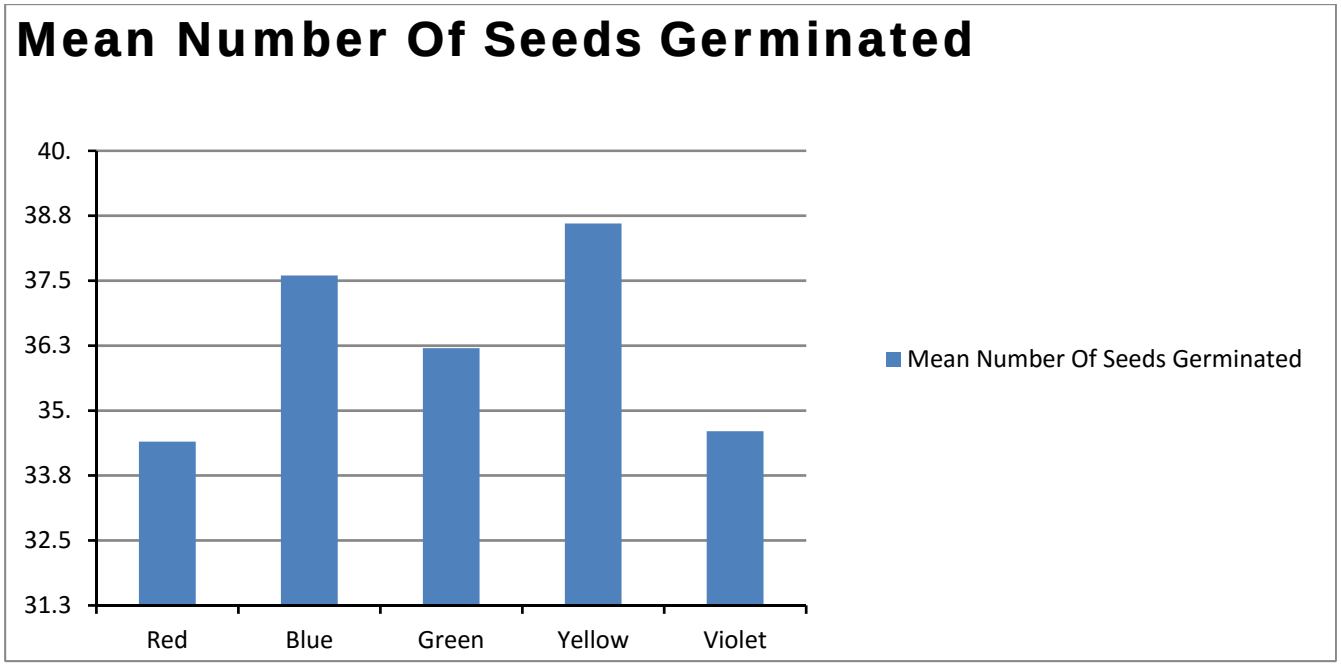

Graph 1. This graph shows the mean number of seeds germinated during 8 days with different wavelengths of light.

In these graphs, it can be seen that average germinated seeds at red is the least one, however its standard deviation is much more higher than green light and blue light. Most sustainable data is blue because its standard deviation is the least one and also it is the most germinated seed.

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Analysis of Variance (One-Way)							
Descriptive Statistics							
Groups	*Sample size*	*Sum*	*Mean*	*Variance*			
Blue Light	5	188	37.6	5.3			
Green Light	5	181	36.2	18.7			
Red Light	5	172	34.4	284.3			
Violet Light	5	173	34.6	3.3			
Yellow Light	5	193	38.6	2.8			
Total	25		36.28	55.21			
ANOVA							
Source of Variation	*d.f.*	*SS*	*MS*	*F*	*p-level*	*F crit*	*Omega Sqr.*
Between Groups	4	67.44	16.86	0.26813	0.89498	2.86608	-0.13263
Within Groups	20	1,257.6	62.88				
Total	24	1,325.04					

Table 3. ANOVA application for the experiment of germinated seed under the influence of different wavelengths of light.

The reason why I did this is, I want to look over all the statistical values to see the validity of the results that I have obtained from this experiment. Most important statistical value that shows the validity of the the experiment is p-level because if this value is under the 0.05 It can be said that your experiment is valid. Therefore p-level for my experiment was calculated as 0.89498 so the data that I have obtained is not significantly different from each other. However, I want to discuss the reasons for my experiment to called as not valid. First thing came up to my mind is while I was doing the trial for red light, I have seen that most of

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the seedlings endoskeleton at the centre of the germination pot breaken down, I don't have any absolute answer for this problem but I guess it is because of the distance between light source and seeds are so small that seedlings become denatured because of the intensity of light. I have observed this situation mostly on red light because red light has the maximum wavelength so that standard deviation is too much for the data at red light. If we consider my hypothesis seeds should germinate better under the influence of red light. Also I didn't close the lights at the same hours in a day. Sometimes seeds take 14 hours light in a day and sometimes they take only three hours. Although the total insolation times are same for each trial, insolation times in a day effect the germination.

This experiment couldn't be finished at the expected time because of my schoolworks so time taken for this experiment get longer so it becomes harder to keep the temperature constant, because at Ankara temperature change during the day and night Therefore the temperature of the room that I have make this experiment changes like ± 3 degrees and temperature has an non-ignorable affect on germination of lettuce seeds because lettuce seeds are also thermo dormant seeds.

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Conclusion and Evaluation:

In this experiment, my aim is to observe the effects of increasing of the wavelength on the germination of lettuce seed by using, red light 650nm, green light 510nm and blue light 475nm.

In this investigation, I observed the germination of *Lactuca Sativa*. As I mentioned before, plants have four important processes throughout their lives such as photosynthesis, fertilization, maturation and germination. Simply, "Germination is the process by which a plant grows from a seed."[1] If conditions are suitable for seed to emerge from the seed, it germinates to form a seedling.

In my experiment, I have used 4 stripes of led light which was convertible to every visible light in order to see the effects of change in the wavelengths on the germination of seeds. I used one 55cm long germination pot on the each of the wavelengths and in order to have more accurate and fast results I divided the 55cm long germination pot to 5 equal parts each with 11 cm long 14cm width. It also increases the number of trials. Then I used 600mL tap water at 18C° in order to pour it on seeds. Also I used a room temperature in order to see the change in temperature.

First I get one 55 cm long germination pot and the divided it to five equal pieces with putting some cardboard with the width of 14 cm and the height of 6 and I get 5 equal parts each with 11 cm. you got to be careful about dividing it to equal parts in order to prevent inaccuracy. Then I got new cotton and I put these cottons to the each equal parts, it is important to use the same cotton and also to putting the same size of cotton because if you use different cottons there is an inaccuracy occurs which was because of change in the absorption of the water of cotton. Then I took the transparent cover of the pot and fix the lights to the inside of the cover.

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Be careful to putting the led lights with 4cm apart so that each part of the pot can take equal lights. After that I put the 250 lettuce seed to the 5 divided parts each with 50 seeds. Then I poured 150 mL of water to the divided parts each with 30 mL water at 18C°. I closed top of the transparent cover of the pot with the help of towel and put the room temperature to the upper side of the cover so that I can see the change in the temperature. After waiting for five days I poured 50 mL of water each part with the 10 mL of water at 18C°. Finally as 3 days after pouring (totally 8 days) I have collected the data. Be careful to insolate the parts 80 hours totally. Then I have repeated these steps with 4 more different wavelengths of light.

In this experiment, I observed the effects of wavelength of the light on the germination of seed of *Lactuca Sativa*. As it can be seen from graph 1. mean number of germinated seeds versus different wavelengths, there is a significant effect of the wavelength of the light on germination of lettuce. After making the required calculations, it is seen that mean number of germinated seeds for red light is 34.4, for yellow light 38.6, for green light is 36.2, for blue light is 37.6, for violet light is 34,6. In order to conclude accurately, percentages of germinated seeds are calculated and it is found that there is a percentage of 68.8% for red light, %77.2 for yellow light, %72.4 for green light, 75.2% for blue light, for 69,2% for violet light.

According to the experiment that was performed by Windham High School, 88% of the seeds insolated with the red light germinated, 72% of the seeds insolated with the green light germinated and 26% of the seeds insolated with the blue light germinated.

In this investigation, as it can be seen from Table 1. I controlled some variables in order to see the effect of different wavelengths of light on the germination of *Lactuca Sativa* accurately. However I cannot keep some of the variables constant such as temperature and sometimes encountered with some problems. For instance, I made 5 trials for 8 days then I

[1]: http://en.wikipedia.org/wiki/Germination
[2]: http://www.highmowingseeds.com/sb-factors-affecting-germination-of-organic-seeds.html
[3]: http://bioted.tedankara.k12.tr/lnotes.php
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made 5 more trials with another light after it finished I made 5 more trials with another light so it takes nearly 1 month so the temperatures of the room always change like 3 C° more or 3 C° less than room temperature. So it has an non-ignorable effect on germination of the lettuce seeds because lettuce seeds are also thermo dormancy seed. Also I didn't open the lights always at the same time and also I didn't close the lights at the same hours in a day. Sometimes seeds take 14 hours light in a day and sometimes they take only three hours. Although the total insolation times are same at all lights, insolation times in a day effect the plant. I observed that I give 3 days over and over 15 hours of light so plants puckered up and they can not germinate efficiently and it cause an uncertainty. Finally when I touch the cottons after the experiment they were still so wet and ı thought that I gave them too much water. However I gave each of them same volume of water.

So, in the next time, in order to have more accurate numerical results and relevant data, I am going to be more careful with planning the experiment and to have a good research about the reagents optimums. Such as, I believe that if I had well planned the hours opening and closing I get more observable and sustainable data.

After this investigation, I believe that I have explanatory knowledge and sufficient data to discuss the effects of different wavelengths on the germination of seeds. However my data are not the same with my expected results.

My data show the inverse of my hypothesis, I said that as we increase the wavelength of the light germination rate will increase however my data says that as we decrease the wavelength germination rate will increase. According to the research I made my hypothesis is true, I thought that this caused because of my systematic errors that I have mentioned before.

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