Investigating the effect of different soil depth on germination speed of the Lens culinaris seeds

Extended Essay (Biology)

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Abstract

Germination is defined as a plant emerging from a seed after a period of dormancy.[1] A research question is formed; 'Does different soil depths have an effect on germination speed of the *Lens culinaris* seeds?' An experiment is designed to investigate. *Lens culinaris* seeds are used, because the volume and shape of the seed being convenient. The volume and mass of *Lens culinaris* seeds are small, and the shape is round. These features are the perfect fit for the experiment, because the depth of the seeds will be changed and it is important to reduce the errors while planting the seeds. There are also lots of types of Lens culinaris seeds for example, Indian brown, French Green, Red Chief lentil…[2] In the experiment, Indian brown lentil seed types are used, this type of seed can be found in every grocery store. 35 seeds were planted in 35 cups with different depths each 5 trial. They were all tried to be kept in same conditions and each of them was watered 10 ml day by day. The day and time were recorded when the seeds planted and the time when seeds germinated, and by this process, the time taken for the germination is calculated. The germination process of the seeds in all of the trials was controlled per 2 hours between the hours 08:00 and 23:00 pm.

After the experiment, the results confirmed the alternative hypothesis. ANOVA One Way statistical analysis is made to compare the data in the experiment. The p-value found in this analysis was 1.57×10^{-5}, which is smaller than the alpha value(0.05). Therefore, the *Lens culinaris* seeds planted near the surface emerged from the soil quicker than the other seeds.

Word Count: 284

[1] http://www.britannica.com/EBchecked/topic/231783/germination (03.01.2011 14:45)

[2] http://www.foodsubs.com/Lentils.html#brown lentils (03.01.2011 14:45)

Contents

Page

Investigating the effect of different soil depth on germination speed of the Lens culinaris seeds

Introduction

The graduates say, the hardest part of writing the extended essay is choosing the subject. It was also very challenging to find a topic. I contrived this idea during a conversation. One day, my mother told me that a raven, which had a nest in a tree right in front of our house, was stealing our walnuts from our balcony. Ravens are very intelligent creatures that bury their food if it is not necessary at that moment, and they usually do not forget the place where they bury the food.[3]

My mother also told me that, when they forget the food which they buried, the seed would always germinate. Instinctively, the birds bury the food in a very proper depth for germination which humans cannot calculate neatly. I was fascinated and started searching immediately. The first search results included some articles about seed germination in different conditions such as, soil type, plant type, volume of water, quantity of minerals in the soil et cetera. Germination is very important for farmers to have a plentiful harvest so the farmers have to create the optimum conditions very carefully.

For a seed to germinate seed dormancy period must be overcame and optimum natural standards must be created. At optimum temperature and with enough water and oxygen, most of the seeds pass the dormancy status and start to germinate.[4] Some seed species are tolerant to the conditions of the environment that they are in and they can germinate in these conditions, but complete germination will only be achieved under optimum conditions.[5] Also, the genetic characteristics are important in germination process and seed dormancy differs in every seed specie. In an experiment about seed dormancy in different rice species in a range of geographical difference, it is found that ecological differences affect seed dormancy.[6] The dormancy mechanisms of seeds differ from specie to specie.[7]

[3] DWORSCHAK, Manfred., Clever Ravens; Masters of Deceit
[4] http://gardening.wsu.edu/library/vege004/vege004.htm (03.01.2011 15:00)
[5] http://www2.bioversityinternational.org/publications/Web_version/188/ch07.htm (03.01.2011 15:01)
[6] VEASEY E. A., KARASAWA M. G., SANTOS P. P., ROSA M. S., MAMANI E., OLIVEIRA G. C. X., Variation in the Loss of Seed Dormancy during After-ripening of Wild and Cultivated Rice Species
[7] http://www.seedimages.com/dormancy/seed-dormancy.html (03.01.2011 15:07)

Mass of water in soil, the temperature of the soil and volume of oxygen affects the germination. A seed in the dormancy period is mostly dehydrated. So water is an important factor in germination for seeds to overcome, because the seed must absorb water which makes it easy to take off the seed coat and germinate. When the seed is in the dormancy state, usage of oxygen is low. However, in germination, oxygen is necessary for metabolism of the cells. Cellular respiration starts after a plant embryo grows and oxygen is needed for aerobic respiration of the seed until the first leaves are grown. Seeds can germinate in a wide range of temperature but the optimum temperature for most of the plants is room temperature. So, it is inducted that seed species prefer to germinate in spring, where the temperature is warm, optimum for most of the seeds.[8]

In this experiment, the effect of the soil depth in the germination of a seed will be investigated. Farmers generally plant the seeds in a depth that is twice of the diameter of the seed which is not a proven scientific fact.[9] It is important that burying the seed too deep will prevent germination so it must be properly calculated. Especially, small seeds must not be planted too deep because endosperm of the seed, which is food storage of the seed, has small food supply regarding to its size. If small seeds were planted deeply, the food of the seed would be consumed before the seed emerged from the soil and begun photosynthesis. Also, planting too deep will prevent depriving of the seeds of oxygen during germination.[10] On the other hand, seeds that are not planted deep enough may be eaten by birds and planting too close to the surface can result in seed not having enough minerals and water from the soil.

[8] http://www.tutorvista.com/content/biology/biology-iv/plant-growth-movements/affecting-seed-germination.php (03.01.2011 16:06)
[9] http://www.ext.colostate.edu/ptlk/1814.html (03.01.2011 16:06)
[10] http://aggie-horticulture.tamu.edu/Wildseed/growing/germination.html (03.01.2011 16:06)

In this experiment, the organism *Lens culinaris* (Lentil) will be used. It belongs to the kingdom *Plantae*, division *Magnoliophyta*, class *Magnoliopsida*, order *Fabales*, family *Fabaceae.* The reason why I choose this plant is; it can grow quickly and easily emerge from the soil. The seeds can be found easily, also my father is interested in planting them and he is experienced about the growth of the plant. For *Lens culinaris* the seed dormancy is 90 days in natural conditions and the seed dormancy can be overcome in 48 hours in moist soil. The germination must be done in 20°C for *Lens culinaris*.[11] Also, *Lens culinaris seeds* grow well on well drained soil types. The optimum depth for *Lens culinaris* seeds is 2.5 to 4 centimeters.[12]

As it was stated before, it is important for farmers to make sure that the seeds are in optimum conditions for germination to have a good harvest. In this experiment, the optimum depth for the *Lens culinaris* seed will be investigated for better germination. To have a better harvest from the plant, I believe this topic is worthy of investigating.

Consequently, this paper will focus on the research question: 'Does different soil depths have an effect of on germination speed of the Lens culinaris seeds measured in terms of time?' and will discuss whether this is a important factor by making experiments and evaluating them, also analyzing the results.

[11] ERSKINE, W., Techniques of Seed Production in Lentil, Food Legume Improvement Program, ICARDA

[12] http://www.gov.mb.ca/agriculture/crops/pulsecrops/bhf01s01.html

Hypothesis

For farmers, the seed planting is very important. A perfect depth of the soil has a very productive effect for the crops and it is profitable for the farmer. Nowadays the seeds are being planted by the help of technologic devices, but still, the farmer must decide the depth of the seed manually.

Lens culinaris seeds are classified as “large” seeds. These seeds have energy which makes it possible to plant deeper in soil. Planting the seed between 2.5 and 4 centimeters deep is advised. (See Introduction, page 3) Moreover, it is predicted that the seed which is the deepest in soil, will emerge lastly and the seed that is closer to the surface will emerge quickly than the deeper seeds. For the other seeds with depths between the closest to the surface and the deepest in the soil, the emerge day and hour will also be different from each other.

So it can be hypothesized that, **the *Lens culinaris* seeds planted in different depths in soil emerges in different days/hours from each other.**

It is expected that seeds that is the closest to the surface will emerge firstly and the seeds deepest in the soil will emerge lastly. The seeds between those depths will emerge in the days between the emerge time of the closest seeds and the emerge time of the deepest seeds in the soil.

Method Development and Planning

Proving or rejecting the hypothesis, a series of controlled experiments must be made. In this experiment, data collection was a problem. The first idea was measuring the heights of plants after 15 days from sowing of the seeds. However, this method wouldn't give the data needed for the topic; germination. Because in this method, the plant would be all grown and it would have leaves and start to do photosynthesis. At that point, the height of the plant would show the effect of water and rate of photosynthesis. Data of measuring the weight wouldn't give any relevant data about the germination and the depth of the seeds. So, a new method was found by calculating the time taken for germination from the planting day and the day when the first leaves are bloomed. Moreover, to be accurate on germination time, planting the seeds to the inner surface of a transparent cup seemed to be a solution. So, the seeds could be observed, and the time could be recorded when it emerged from soil.

Variable control was another serious issue. All the cups were put under a window, near balcony window and given the same volume of water. Drinking water was given to the plants for pH control. pH the water is included in label of the brand, which is Erikli drinking water with a pH of 7.5 (See Appendix 1), nevertheless the pH was regularly checked. The peat soil with the brand ÖZ TORF was used (See Appendix 2), which is a mineral rich organic soil, was used for all the trials for the seeds to grow healthy. The temperature of the room was regularly checked. Since they are in the same room, water or temperature would affect all of them, so it is not an error.

Measuring the depth of the soil was the hardest part. Using a ruler to measure depth in soil would be very difficult. This reminded me of "Crater" experiment in Physics in which we measured the depth of the crater with a toothpick in flour. The same pattern was practical in measuring the depth of the soil. Measured length was marked on a toothpick by a ruler (for example, to plant a seed in 1 cm depth, 1 cm was marked on the toothpick) and the seed was buried, with the toothpick. It made planting the seed easier and accurate.

Genetics is very important since all the seed dormancy, the height of the plant et cetera depends on the genes. The first thought was planting a few seeds in our garden and harvesting the crop. Then the harvested crop would be the seeds which would be used in the experiment. However, this would take a long time and also there would be a crossing over in the genes of every crop harvested which wouldn't make difference for similarity of the genetics of the experimental seeds. So, these aren't made. However, identical mass, shape, volume and color were selected. So, 40 seeds are selected which have same appearance.

A method is developed in sight of all these variables. I believe this would be the best way to obtain appropriate data to prove or reject the hypothesis that has been made.

Method

Materials and Apparatus:

40 transparent plastic cups
40 Indian brown *Lens culinaris* seeds
2 rulers (10 cm and 30 cm)
25 ml injector (±0.1 ml)
water (Erikli Su, ph: 7.5)
pH meter
5250 grams of "ÖZ TORF"Peat soil
40 toothpicks
marker pen
post-it
a scale (±0.001)

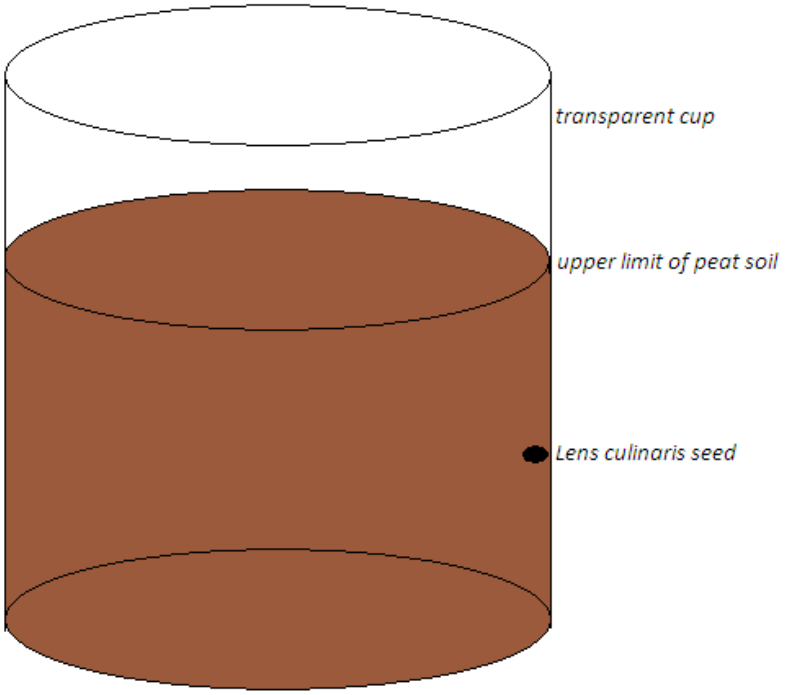
The each 35 transparent plastic cup was filled with 150 grams of peat soil which is measured by the balance. Then all of the plastic cups were separated in groups of five, resulted in 7 groups. Each group was given a name and written into post-its.

A handful of *Lens culinaris* seeds are taken and by the help of the scale, the weight of each of the seeds is measured. The seeds with having weights close to 0.075 grams are chosen. Within these seeds, the size, shape, corrugation of the seeds is controlled and seeds with a medium size, a round shape and non-wrinkled are selected.

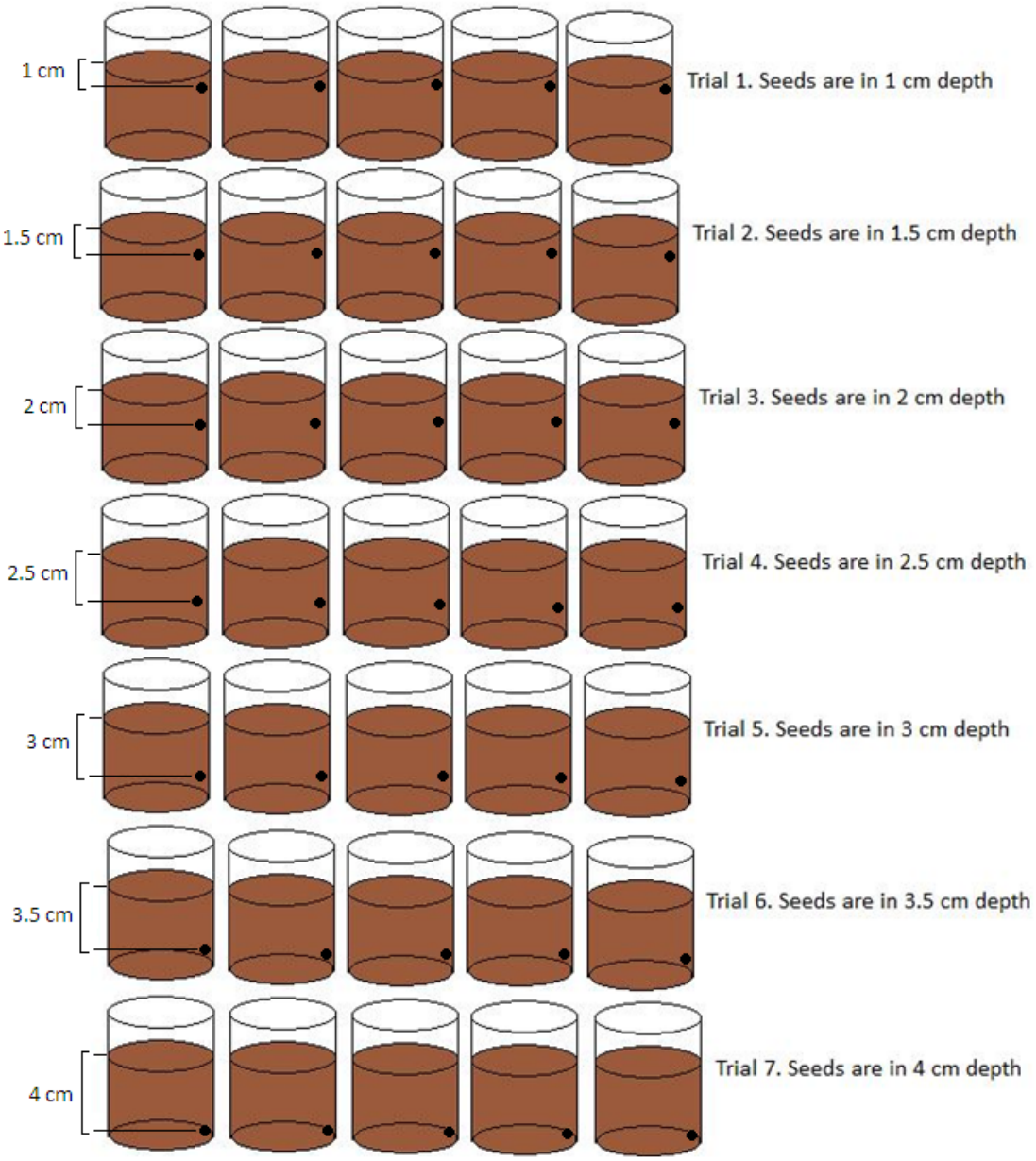
A toothpick was taken for the first trial of the first group. 1 cm was marked on the toothpick. The toothpick was stuck into the soil up to the marked spot with depth of 1 cm from the surface of the soil and a seed was planted carefully to the depth. The seed was planted into inner surface of the transparent cup. It was covered with soil; however, the seed could be seen from outside transparent surface (See Picture 1). The same procedure was applied to other 4 seeds with another 4 toothpicks. The group was named with marker pen and as Trial 1. For other groups same procedure was done. Another 5 seeds and 5 toothpicks were taken, the 1.5 cm depth was marked to the toothpicks and the seeds were planted to 5 plastic cups individually, named as Trial 2. This process was repeated with 1.5, 2, 2.5, 3, 3.5 and 4 cm soil depth by using the rest of the cups, toothpicks and the seeds. (See Picture 2) Initial time, the day/hour of planting was recorded.

All of the plants were watered 10 ml (±0.1 ml) at the same time, per two days around 5 pm. The plants were given the water of the trademark Erikli Su, which has a pH of 7. 5. However, the pH of the given water was regularly checked. Also the volume of water given was kept constant by watering the plants by an injector to reduce errors. The water was given directly upon the soil where the seeds were planted. The plants were kept at the same room to make temperature constant.

Since the seeds could be seen from outside of the cup, the first emerge in the seed was checked per 2 hours between 08:00am and 11:00pm. The seeds weren't controlled at night. The day and hour of when the plant emerged from the soil was recorded.



Picture 1. *An illustration showing the position of planted Lens culinaris seed, right next to the side of a transparent cup.*



Picture 2. An illustration of all the trials

Results

Trial Numbers	Depth of the *Lens Culinaris* seeds (± 0.1 cm)						
	1	1.5	2	2.5	3	3.5	4
	Germination time by means of days/hours/minutes						
1	3 days 5 hours 45 minutes	3 days 5 hours 45 minutes	6 days 19 hours 44 minutes	5 days 5 hours 10 minutes	6 days 1 hours 28 minutes	5 days 6 hours 13 minutes	10 days 5 hours 5 minutes
2	6 days 18 hours 25 minutes	4 days 18 hours 30 minutes	5 days 6 hours 2 minutes	5 days 21 hours 25 minutes	6 days 6 hours 54 minutes	5 days 22 hours 2 minutes	7 days 1 hours 44 minutes
3	3 days 0 hours 45 minutes	4 days 18 hours 30 minutes	5 days 17 hours 22 minutes	5 days 16 hours 15 minutes	6 days 6 hours 20 minutes	6 days 6 hours 23 minutes	8 days 6 hours 38 minutes
4	3 days 5 hours 0 minutes	3 days 5 hours 45 minutes	5 days 17 hours 22 minutes	5 days 8 hours 35 minutes	5 days 7 hours 10 minutes	10 days 7 hours 47 minutes	9 days 5 hours 17 minutes
5	3 days 5 hours 30 minutes	3 days 20 hours 30 minutes	5 days 4 hours 13 minutes	5 days 5 hours 10 minutes	5 days 6 hours 22 minutes	5 days 19 hours 49 minutes	7 days 14 hours 23 minutes

Table 1. *The germination day and time is recorded for each seed in each trial. The uncertainty of the depth of the seed is given 0.1 cm due to the smallest division in the apparatus used.*

	Trial numbers				
	1	2	3	4	5
Depth of the seed (± 0.1 cm)	Germination time by means of hours				
1.0	77	162	72	77	77
1.5	77	114	114	77	92
2.0	163	126	137	137	124
2.5	125	141	136	128	125
3.0	145	150	150	127	126
3.5	126	142	150	247	139
4.0	245	169	198	221	182

Table 2. *The same raw data from Table 1 is calculated in hours only.*

Data Analysis

Depth of the *Lens Culinaris* seeds (± 0.1 cm)	Average Germination Time
1.0	93.00
1.5	94.80
2.0	137.4
2.5	131.0
3.0	139.6
3.5	160.8
4.0	203.0

Table 3. *Mean values of germination time from the Table 2 is calculated by means of hours.*

Depth of the *Lens Culinaris* seeds (± 0.1 cm)	Standard Deviation	Standard Error	Confidence Interval
1.0	38.63	17.28	44.42
1.5	18.57	8.30	21.35
2.0	15.53	6.95	17.86
2.5	7.18	3.21	8.25
3.0	12.14	5.43	13.95
3.5	48.96	21.89	56.29
4.0	30.45	13.62	35.02

Table 4. *Average volume, Standard Deviation, Standard Error and Confidence Interval are calculated for mean values of time taken for germination of Lens culinaris seeds by using Microsoft Excel 2007.(For calculations, See Appendix 4)*

To check if there is a difference between the results (means) statistically; ANOVA test must be made in Microsoft Excel 2007.

The null hypothesis of the experiment indicates that all the mean values of time, taken for seeds in different depths for germination, are equal to each other, which also means that the different depths of *Lens culinaris seeds* don't have any effect on germination. Also the alternative hypothesis of the experiment assumes that at least one of the values is

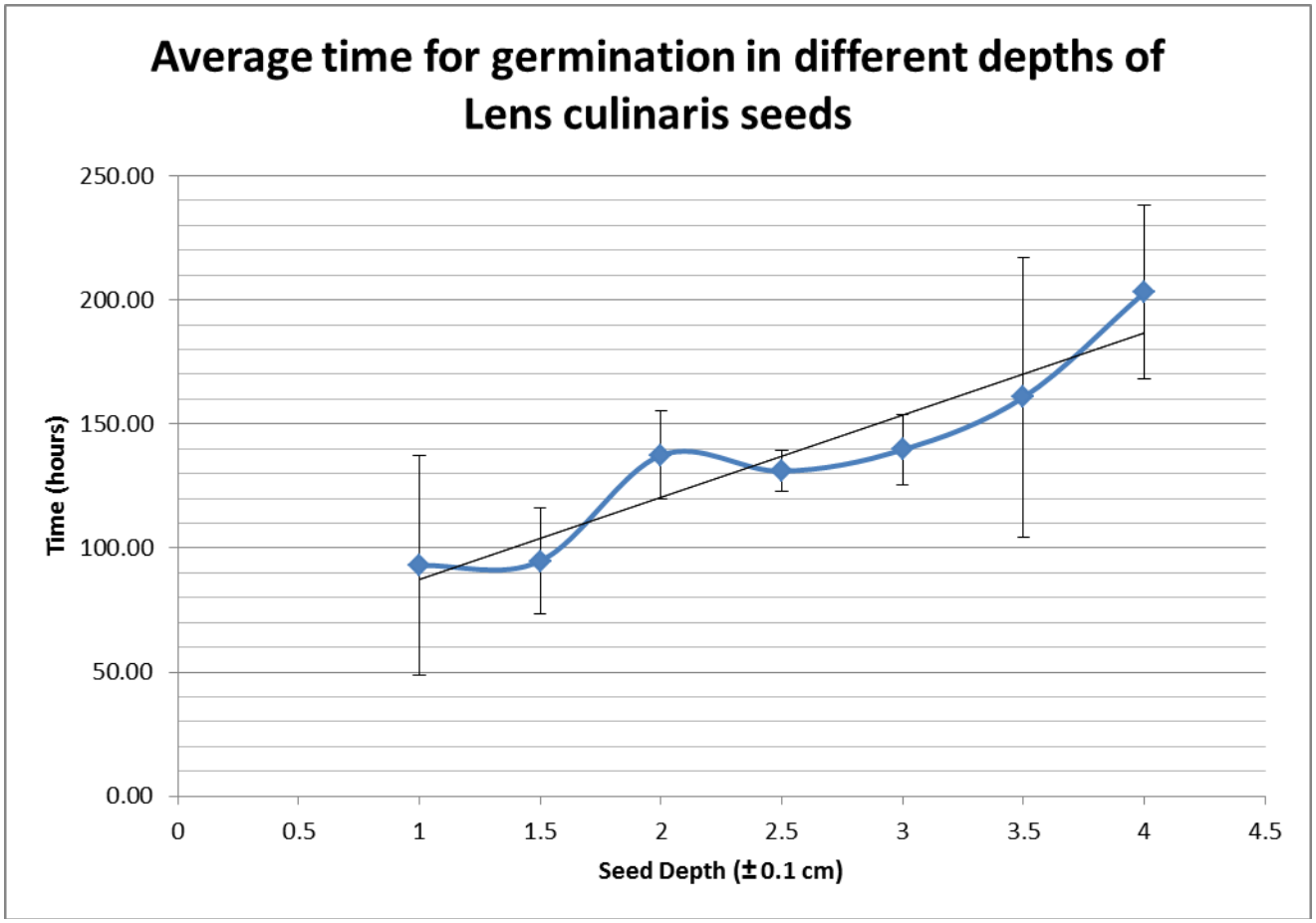
statistically different from the other values which show that different depths of *Lens culinaris* seeds statistically has an effect on germination rate.

ANOVA

Variance Source	SS	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	43410,74	6	7235.124	9.041483	1.57E-05	2.445259
Within Groups	22406	28	800.2143			
Total	65816.74	34				

Table 5. *ANOVA test is made and P-value is found to be 1.57 x 10^{-5}.*

The P-value is 1.57 x 10^{-5}. This value is smaller than alpha value (0.05), so there is a statistical difference between the means of time taken for the *Lens culinaris* seeds to germinate which also means different depths of seed in germination. So, alternative hypothesis is accepted which supports that the lens culinaris seeds planted in different depths in soil emerges in different days/hours from each other.



Graph 1. Average time for germination in different depths of Lens culinaris seeds graph is made by using the mean values of the experiment.

Conclusion and Evaluation

The results of the experiment support the hypothesis that lens culinaris seeds planted in different depths in soil emerges in different days/hours from each other was proven by ANOVA One Way statistical analysis. The result of the ANOVA One Way analysis gave a p-value of 1.57×10^{-5} which is smaller than the alpha value of 0.05(See Data Analysis), by this result the null hypothesis which assumed that there isn't any difference between the means of data was rejected and alternative hypothesis, claiming at least two of means of the experiment was different from each other statistically was approved.

Seeds with different depths emerged from soil in different days, averagely for seeds with 1 cm depth it took 3 days, for seeds with 1.5 cm depth it took 3 days, for seeds with 2 cm depth it took 4 days, for seeds with 2.5 cm depth it took 5 days, for seeds with 3 cm depth it took 5 days, for seeds with 3.5 cm depth it took 6 days and lastly for seeds with 4 cm depth it took 8 days. So it can be seen that first seeds to emerge from the soil were the seeds with 1 and 1.5 cm depth. The effect of seed depth in soil couldn't be observed in seed depths with shorter length difference in between; there was clearly no absolute distinction between the seed depth in soil of 1 and 1.5 centimeters as all seeds in this two trials emerged from soil nearly the same days. However, effect of seed depth in soil could be clearly investigated with the trials with having longer depth difference between; for example, the distinction of the germination speed could easily be noticed between the trials of 1 and 3 centimeters. As it was stated before (See Introduction, page 3), the optimum depth was between 2.5 and 4 centimeters. However, as the results of the experiment indicate, the quickest to germinate was the seeds with 1 and 1.5 cm depth in soil. This proves, farmers planting in twice of the diameter of the seed rule (See Introduction, page 2). In this experiment, the seeds had a diameter of 0.5 cm. So, the seeds should be normally buried to 1 cm deep. Results of the experiment show that the farmer's method is more useful.

My hypothesis expecting for all of seeds with different depths in soil to emerge in different days was proved. The conclusion that can be made from the results is, deeper the seed, longer the germination period. It is obvious that the deeper seeds have to emerge through a thicker soil layer, but there is also the oxygen factor for the seeds. Oxygen is a factor for germinating seeds. More oxygen means more energy for the germinating seed so it also means quicker growth. The seeds which are deeper in the soil may have a lower contact with oxygen than the seeds near the surface. The reason of early germinating of the seeds sowed near the surface than the others may be the access of air, containing oxygen. As oxygen is used in metabolic reactions of the cells during germination, the time taken for all the seeds to germinate found to be different for all five trials, the reason of this may be the oxygen levels for each depth as it changes from depth to depth.

The properties of the environment were tried to be kept constant, such as temperature, pH of the water, volume of the water, available oxygen. During the experiment the temperature of the room constantly changed because of weather conditions. However, all of the trials were in the same room and the temperature change affected all of the cups at the same time so it is a constant for seeds. Moreover, vaporization was another problem because generally the room temperature was high, but again, all of the cups were placed together and the surface area of the soil in the cups were all the same, so it is considered as a constant variable.

The pH of the water was constantly checked with a pH paper, there was not any particular difference in pH of the paper given to all of the cups, day by day. For this reason, the pH of the water given to the cups didn't make a difference between the growths of the seeds. The volume of the water given to the seeds was constant for all the trials. 10 ml was given to the cups in all of the trials. The available oxygen for the seeds was an independent variable. The seeds were all in the same room the available oxygen in the air was same for all seeds. However, the deepest seeds were not able to contact with the oxygen available in air and the seed closer to the surface. This is a reason of late emerging of the seed.

When the graph was examined (See Data Analysis), there is not a straight line formed by the means of the trials. The mean value of the trials with the seed depth of 2 centimeters is causing this curved shape in the graph. It could be interpreted that there is an error in the experiment causing this abnormality. However, it is obvious that there is a significant mean difference between the means of the trials. The regression line of the mean values clearly shows that the seed depth and time for germination process are directly proportional to each other. The error bars of the graph are drawn by the Confidence Interval

values of the data of the experiment. The reason of this huge error bars could be the errors made in the experiment.

Though the constant variables were kept as constant as possible, there were errors that I could not prevent. Although, the seeds used in the experiment were selected in same weight, color and shape. There could still be different genetic make-up of the seeds which will affect the germination and the soil emerge time. The gene sequences in the DNA s of the seeds could be a factor that is hard to keep constant. In order to decrease this difference and protect the hereditary qualities of the *Lens culinaris* seeds, particular seeds could have been used which were fruited by an ancestor *Lens culinaris* plant. This ancestor plant must also be forced to self pollinate. However, this improvement will not make the genotypes and the phenotypes of the offspring the same. Even though the plant is self pollinating, there is a crossing over period in the meiosis of the egg or the sperm which makes it impossible to be sure of the genetic make-up of the offspring. This is a huge limitation of the experiment. This genetic make-up is also effective in seed dormancy, the absorption of water from the soil and oxygen usage of the seed. Ability to absorb water or oxygen could have been less in some seeds which would greatly affect germination process.

Moreover, though the volume of the soil was measured, some small particles and stones were found in the soil. These particles also created some air spaced in the soil, which would affect the germination process since the seed required oxygen. Also, the water absorption of the seed might have decreased. There were also some grass-like plants that grew in the cups, the seeds or the spores were probably came with the soil itself, which would possibly decrease the water absorption of the *Lens culinaris* seeds. They were ripped as soon as possible. Though the seeds were watered right above the sown seed, because of this particles and grass-like plants the water might not have reached to the seed properly. (For illustration, See Appendix 4) This may not be a problem for the seeds near the surface but the seeds with larger depth in soil. In order to improve this, the soil could have sieved and particles, roots could have been cleaned.

To conclude, the seed depth is an important factor in germination process. As the result of the experiment indicates, in order to have quickest efficiency from the *Lens culinaris* seeds, the seeds must be planted not too deep. As understood from this experiment, the optimum depth for germination of the *Lens culinaris* seeds is 1 or 1.5 cm deep, which is also the twice of the diameter of the *Lens culinaris* seed. So, in order to have a quicker harvest, the germination speed would also be affective. For farmers desiring for a quicker harvest for the Lens culinaris plant the optimum seed depth should be between 1 or 1.5 cm. This would also be both profitable for the farmer and the market of the country.

Appendices

Appendix 1

Ingredients of 'Erikli Su'

(http://www.erikli.com.tr/images/stories/5-v-analiz-sertifikasi.jpg)

Boron (mg/L B) : 0.01
Copper (mg/L Cu) : None
Fluorine (mg/L F) : None
Nitrate (mg/L NO3) : None
Nitrite (mg/L NO2) : None
pH : 7.5
Sulphate (mg/L SO4) : 3.4
Sodium (mg/L Na) : 1.4

Appendix 2

Soil: ÖZ TORF
pH: 4-7
Ingredients: 2195 ppm Iron (Fe), 13 ppm Copper (Cu), 38 ppm Manganese (Mn), 32 ppm Zinc (Zn)
% 1.186 total Nitrogen (N), % 0.215 Phosphorus (P), 1800 ppm Potassium (K), 2800 ppm Calcium (Ca), 1620 ppm Magnesium (Mg), 200 ppm Sodium (Na)

Appendix 3

Picture 3. The photo shows the germination of *Lens culinaris* in the transparent plastic cup planted in two centimeters deep within the soil at day 4.

Picture 4. The photo shows all of the trials at day 4

Appendix 4

Calculating the mean, Standard Deviation, Standard Error and Confidence Interval of the hours taken for the germination of the *Lens culinaris* seeds is important in ANOVA One Way statistical analysis and commenting on the results of the experiment.

The average hours taken for the germination of the seeds is calculated from the formula:

$$\bar{x} = \frac{(\sum x)}{n}$$

For example; for the trials of 1 cm seed depth in soil;

$$77 + 162 + 72 + 77 + 77 = 465$$

$$465 \div 5 = 93$$

The Standard Deviation for the hours taken for the germination of the seeds is calculated from the formula:

$$\sigma = \sqrt{\frac{\sum(x - \bar{x})^2}{N}}$$

For example; for the trials of 1 cm seed depth in soil;

Deviations:

$$(77 - 93)^2 = 256$$

$$(162 - 93)^2 = 4761$$

$$(72 - 93)^2 = 441$$

$$(77 - 93)^2 = 256$$

$$(77 - 93)^2 = 256$$

Sum of Deviations:

$$256 + 4761 + 441 + 256 + 256 = 5970$$

Divided by one less than the n (# of trials):

$$5970 \div 4 = 1492.5$$

Square root of this number:

$$\sqrt{1492.5} \approx 38.63$$

The Standard Error for the hours taken for the germination of the seeds is calculated from the formula:

$$Standard\ Error = \frac{Standard\ Deviation}{\sqrt{n}}$$

For example; for the trials of 1 cm seed depth in soil;

$$S.E. = \frac{38.63}{\sqrt{5}} \approx 17.28$$

The Confidence Interval for the hours taken for the germination of the seeds is calculated from the formula:

$$Confidence\ Interval = Standard\ Error \times t$$

For example; for the trials of 1 cm seed depth in soil;

$$C.I. = 17.28 \times 2.571 \approx 44.42$$

(the t is taken 2.571 because of the trial number)**

** http://people.bu.edu/abramsb/courses/past/F08_CH109/files/statshandout.pdf (10.01.2011 22.41)

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