TED ANKARA COLLEGE FOUNDATION HIGH SCHOOL

Effect of Daily Use Products on the Germination of Plants *Phaseolus vulgaris* (bean) and *Pisum sativum* (Pea)

Biology Extended Essay

Supervisor: Ümit Yaşatürk Midilli

Name of student: Yağız Efe Mertol

Candidate number: 001129 -0009

Word Count: 3774

Abstract

The reason I have chosen this topic for my investigation was that my true belief of the fact that the result of this investigation can affect our daily lives. While discussing about my topic, a teacher of mine, Ümit Midilli, has raised the research question in my mind.

Through my process of investigation and experiments, I have fulfilled my goals and reached a conclusion about the effects of daily used products on the germination of plants. By the conclusion I have reached, people who have questions like mine can have answers to them and further projects can be done on this subject.

Table of Contents

Yağız Efe MERTOL,1
001129 -0009

INTRODUCTION

The seed of a plant is a production like a package which occurs after the combination of male and female sex cells. Germination is the stage of a plant that grows from a seed to a seedling. Seeds require specific conditions to germinate into a seedling and they will remain inactive until all the conditions have been reached internally and externally.

Most common extrinsic factors affecting the germination of a seed is composed of water percentage, oxygen level, temperature and light in some situations. All these conditions need to occur in combination to make the seed germinate. When conditions are achieved, water and oxygen are taken through the seed coat and embryo's cells start to grow.

There are conditions that can cause poor germination in seeds. Overwatering can prevent seed from reaching enough oxygen. Planting seeds too deeply can cause the seed to finish all their energy stored in the seed before reaching the ground of soil. Dry conditions cause the seed to be unable to start germinating by breaking out the seed coat.

The intrinsic factor of germination speed is the quality of the seed. Some plants produce seeds called empty seeds that lack embryos from time to time. The other factor is seed dormancy which causes some seeds to require specific environmental conditions to germinate.

Seeds require taking significant amount of water because of the dry weight of the seed. Enough water will moisten the seeds without soaking them. Imbibition is the process of uptake of water which leads to the swelling and the breaking of the seed coat. Most plants reserve

some food in their seeds in form of proteins and lipids. When water is imbibed into the seed, enzymes start to convert the food into energy until the level of seedling can manage to start photosynthesis.

This need of water for the process of germination has raised the question: *"What if we use any daily use products to water the seeds?"* in my mind. As we have a lot of drinks that gets wasted, some interesting answers to my question can help people about germination.

Some research have also been made by other people that were curious like me. Majority of these research are about the effect of different type of water on germination (For example: Effect of soft water and hard water on the germination of a seed.)

I have decided to choose *Phaseolus vulgaris* (bean) and *Pisum sativum* (pea) as my plants because of the fact that they can germinate faster and easier than most of the plants.

The liquids I will be using on my experimentation can be listed as tea, coffee, milk, apple juice, tap water, sugar solution and buttermilk. I have chosen these liquids because of the fact that these are the most commonly used products on our region.

Yağız Efe MERTOL,3
001129 -0009

METHOD DEVELOPMENT

Effect of Caffeine on the Germination of a Seed

Caffeine is a product that occurs in some of the daily used products such as tea and coffee which are the ones I will be using in my experiment. Caffeine is a psychoactive drug which stimulates the central nervous system of a human body. Even if it is classified as a drug, it is not considered as illegal in nearly all parts of the world. Caffeine has both negative and positive effects on human health. It can even prevent you against some types of cancer or Parkinson's disease, but when consumed more than it should be, it results in cardiovascular diseases such as coronary artery. As it has effects like increasing heart rate and productivity in most of the people, it is consumed widely all around the world. Many gardeners around the world are known to add coffee to the soil of any plants in order to make them grow faster. However, plants haven't got a nervous system as humans do so it does not seem to be logical that caffeine can affect the plant growth directly.[1] As I think that the stimulation effect of coffee can be caused by the ingredients like potassium and phosphorus in it, I am planning to compare coffee with another caffeine containing product. Tea looks like a nice one to compare because I can't reach to caffeine tablets as they are illegal in Turkey.

Yağız Efe MERTOL,4
001129 -0009

Effect of Sugar on the Germination of a Seed

Sugar is a basic material which can be found in a huge variety of products. By the way, it is the product that keeps every living organism alive and running. As it is present in nearly everything we eat, humans don't need to produce sugar by themselves to stay alive. But the situation is opposite on plants. As plants are the main producers in the food chain, they produce glucose through their chlorophylls that are mostly found in the cells of green part of a plant. Most of the plants store the glucose they produced in the form of starch.[2] As they grow seeds, starch is stored in seeds to grant enough food source for the germination process. There are a lot of researches about the effect of sugar solutions on the growth of a plant mostly granting the result that sugar solutions help the growth of a plant, but there are way too less researches made on the subject *"effect of sugar solutions on the germination process of a seed".* So I decided to aim my research on this content. I am guessing that the seed will germinate better and stronger by the help of the extra food source. But there is still a probability that this will limit the amount of water that could be taken inside the seed.

Yağız Efe MERTOL,5
001129 -0009

Effect of Milk and Milk-based Products on the Germination of a Seed

Milk is an animal based product which contains huge amount lactose and calcium in its content. Because of its calcium content it is a widely used product in today's generation. Calcium is a product that stimulates bone growth in human body. Babies and children need to take enough calcium to complete their growth properly. Like milk's effect of growth on the body of a human, calcium also effects the growth of a plant in general. Known effects of calcium deficiency on plants can be listed as the problem of root's being unable to grow properly and the seeds being low on quality.[3] As it stimulates the root growth, it will probably affect the speed of germination on *Phaseolus vulgaris* (bean) and *Pisum sativum* (Pea) seeds. Through my research, I found that there are a lot of opposite results on this subjects so I wanted to try it by myself. I will be using both milk and a milk based product buttermilk because of the fact that they both contain different type of bacteria in themselves. Using both of these products will grant me the information of the effects of these bacteria.

Yağız Efe MERTOL,6
001129 -0009

RESEARCH QUESTION

“How does daily used products affect the germination process of *Phaseolus vulgaris* (bean) and *Pisum sativum* (pea) seeds?”

HYPOTHESIS

Germination of a seed is affected by many intrinsic and extrinsic factors.

-Coffee is used to stimulate plant production on some parts of the world by gardeners so I am considering the probability of caffeine can result in the stimulation of germination *Phaseolus vulgaris* (bean) and *Pisum sativum* seeds. My first two liquids are tea and coffee which has caffeine in their structure so I think that these two liquid will fasten the germination stage of my plants.

-My next liquids are apple juice and sugar solutions which have a high rate of sugar in them so my hypothesis is that these will also stimulate and grant nice effects on the germination stage.

-Last two products are milk and another milk based product buttermilk. As both of them contain high levels of calcium, I believe that they will reduce the availability of water to the seed because of the research I made before my experiment.

Yağız Efe MERTOL,7
001129 -0009

MATERIALS

- 7 flowerpots (of size 20 cm width x 60 cm length x 10 cm height) which can contain 10 seeds each
- 35 bean and 35 pea seeds
- 7*50ml tea solutions
- 7*50ml coffee solutions
- 7*50ml milk
- 7*50ml buttermilk
- 7*50 ml apple juice
- 7*50ml sugar solution
- 7*50ml tap water
- 1 ruler
- 7 packages of cotton of brand Lux (200 grams each package)

Independent Variable	Type of solution added to each pot.
Dependent Variable	Number of germinated seeds in each of the pots.
Controlled Variables	1. Brand (Lux) and mass (200g) of cotton in each pots. 2. Size of (20 cm width x 60 cm length x 10 cm height) each pot. 3. Environmental factors of each pot (kept in the same room) 4. Millilitres of solution provided to each pot (50 ml each day)

Yağız Efe MERTOL,8
001129 -0009

METHOD

1. 7 flowerpots are filled with 200 grams (exactly 1 package of cotton from the brand “Lux”) of cotton in each pot.
2. Pots will be placed in the same room.
3. 5 bean and 5 pea seeds will be planted to same depth on each flowerpot.

EVERYDAY:

1. One of the pots will be watered with 50 ml milk.
2. One of the pots will be watered with 50 ml buttermilk.
3. One of the pots will be watered with 50 ml tea solution.
4. One of the pots will be watered with 50 ml coffee solution.
5. One of the pots will be watered with 50 ml apple juice.
6. One of the pots will be watered with 50 ml sugar solutions.
7. One of the pots will be watered with 50 ml tap water.
8. Each of the seeds will be observed for identifying the first day that it grows the first green leaf.
9. After seven days, data of the number of germinated seeds each day in each pot will be processed to a table.

Yağız Efe MERTOL,9
001129 -0009

Results: Table 1: Raw Data of Seeds Germinated on Each Days ,

n: Number of germinated seeds in each trial

		Day 1		Day 2		Day 3		Day 4	
Type of Solution	Trials	Peas Germinated $\pm\sqrt{n}$	Beans Germinated $\pm\sqrt{n}$	Peas Germinated $\pm\sqrt{n}$	Beans Germinated $\pm\sqrt{n}$	Peas Germinated $\pm\sqrt{n}$	Beans Germinated $\pm\sqrt{n}$	Peas Germinated $\pm\sqrt{n}$	Beans Germinated $\pm\sqrt{n}$
Tap Water	1	0	0	0	0	1	2	0	1
	2	0	0	0	0	2	1	0	1
	3	0	0	0	0	0	3	0	1
Juice	1	0	0	0	0	0	0	0	1
	2	0	0	0	0	0	0	0	1
	3	0	0	0	0	0	0	0	1
Sugar Solution	1	0	0	0	0	0	0	1	1
	2	0	0	0	0	0	0	1	1
	3	0	0	0	0	0	0	1	1
Coffee Solution	1	0	0	0	0	1	0	0	0
	2	0	0	0	0	0	0	0	0
	3	0	0	0	0	2	0	0	0
Tea solution	1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0
Milk	1	0	0	0	0	1	0	1	0
	2	0	0	0	0	2	0	1	0
	3	0	0	0	0	0	0	1	0
Buttermilk	1	0	0	0	0	1	1	2	1
	2	0	0	0	0	1	1	3	1
	3	0	0	0	0	1	1	1	1

		Day 5		Day 6		Day 7	
	Trials	Peas Germinated $\pm\sqrt{n}$	Beans Germinated $\pm\sqrt{n}$	Peas Germinated $\pm\sqrt{n}$	Beans Germinated $\pm\sqrt{n}$	Peas Germinated $\pm\sqrt{n}$	Beans Germinated $\pm\sqrt{n}$
Tap Water	1	1	0	0	0	0	0
	2	1	0	0	0	0	0
	3	1	0	0	0	0	0
Juice	1	1	0	0	0	0	0
	2	1	0	0	0	0	0
	3	1	0	0	0	0	0
Sugar Solution	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
Coffee Solution	1	0	1	0	0	0	0
	2	0	2	0	0	0	0
	3	0	0	0	0	0	0
Tea solution	1	0	1	0	0	1	0
	2	0	0	0	0	1	0
	3	0	2	0	0	1	0
Milk	1	0	1	0	0	0	1
	2	0	1	0	0	0	2
	3	0	1	0	0	0	0
Buttermilk	1	1	0	0	0	0	1
	2	1	0	0	0	0	0
	3	1	0	0	0	0	2

Yağız Efe MERTOL,10
001129 -0009

Table 2: Average Number of Seeds That Germinated and the standard deviations of the data

	Mean Number of Seeds That Germinated		Standard Deviation		Standard Error		Confidence Interval	
Group	Peas	Beans	Peas	Beans	Peas	Beans	Peas	Beans
Tap Water	2	2	0,29	1,28	0,16	0,74	0,25	1,12
Juice	1	4	0,71	0,72	0,41	0,42	0,62	0,63
Sugar Solution	1	4	0,71	0,72	0,41	0,42	0,62	0,63
Coffee Solution	1	4	0,71	0,72	0,41	0,42	0,62	0,63
Tea solution	1	4	0,71	0,72	0,41	0,42	0,62	0,63
Milk	2	3	0,29	0,28	0,16	0,16	0,25	0,25
Buttermilk	4	2	2,29	1,28	1,32	0,74	2,01	1,12
Mean	1,71	3,28						

Table 3: Germination Percentage

	Germination Percentage	
	Peas	Beans
Tap Water	20%	20%
Juice	10%	40%
Sugar Solution	10%	40%
Coffee Solution	10%	40%
Tea solution	10%	40%
Milk	20%	30%
Buttermilk	40%	20%

Yağız Efe MERTOL,11
001129 -0009

Sample Calculation

Pea Seeds That Germinated in Tap water;

Mean: $\bar{x} = \frac{x_1 + x_2 + x_3 + \ldots\ldots\ldots + x_n}{n}$ $\frac{2+2+2}{3} = 2$

Standard Deviation: $\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$ $|2 - 1{,}71| = 0{,}29$

Standard Error: $SE_{\bar{x}} = \frac{s}{\sqrt{n}}$ $\frac{0{,}29}{\sqrt{3}} = 0{,}16$

Confidence Interval: $SE \times t$ = 1,51 x 0,74

Percentage Calculation: $\frac{2}{10}\ x\ 100 = \%20$

Yağız Efe MERTOL,12
001129 -0009

Peas

H_0: There is not a significant difference between mean number of germinated pea seeds and the data occupied through each pot watered with different solutions.

H_1: There is a significant difference between mean number of germinated pea seeds and the data occupied through each pot watered with different solutions.

Beans

H_0: There is not a significant difference between mean number of germinated bean seeds and the data occupied through each pot watered with different solutions.

H_1: There is a significant difference between mean number of germinated bean seeds and the data occupied through each pot watered with different solutions.

Anova: Two-Factor Without Replication

Summary	*Count*	*Sum*	*Average*	*Variance*
Tap Water	2	4	2	0
Juice	2	5	2,5	4,5
Sugar Solution	2	5	2,5	4,5
Coffee Solution	2	5	2,5	4,5
Tea solution	2	5	2,5	4,5
Milk	2	5	2,5	0,5
Buttermilk	2	6	3	2
Peas	7	12	1,714286	1,238095
Beans	7	23	3,285714	0,904762

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	1	6	0,166667	0,084337	0,995827	4,283866
Columns	8,642857	1	8,642857	4,373494	0,081453	5,987378
Within	11,85714	6	1,97619			
Total	21,5	13				

Result:

Peas

H_0 can be considered as true because the p-values I gained are higher than the level of 0,05. Type of solution used to water the seeds has not affected the rate of germination of the pea seeds considerably.

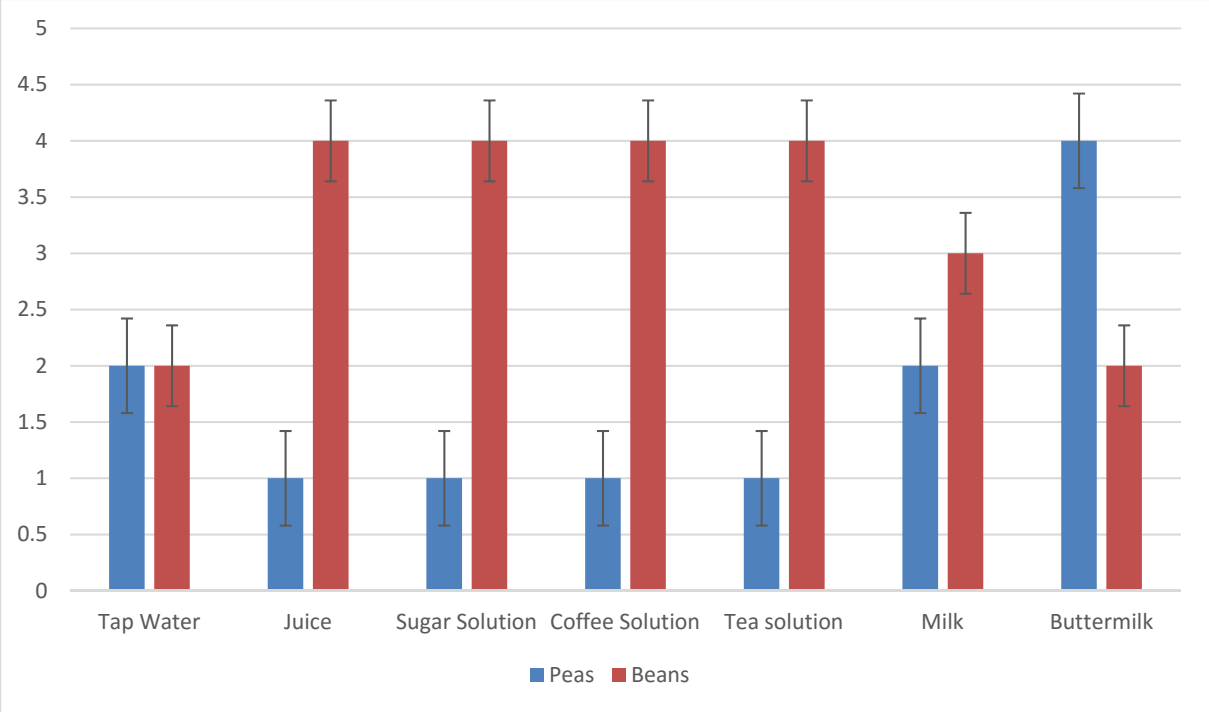
Beans

H_0 can be considered as true because the p-values I gained are higher than the level of 0,05. Type of solution used to water the seeds has not affected the rate of germination of the bean seeds considerably.

Yağız Efe MERTOL,13
001129 -0009

Graph: Mean number of Pea and Bean seeds germinated with different type of solutions.

Error bars represent standard deviation.



Yağız Efe MERTOL,14
001129 -0009

Photos: Pot watered with tea, buttermilk, tap water and sugar solutions.

Yağız Efe MERTOL,15
001129 -0009

Photos: Pot watered with juice and pots before they are watered.

Yağız Efe MERTOL,16
001129 -0009

Photo:

Pot watered with coffee has painted the seed into its colour.

Photo: Pot watered with Juice got moldy.

Photo: Pot watered with tap water has managed to germinate seeds.

Yağız Efe MERTOL,17
001129 -0009

Summary of Results

As we examine the results, the most surprising fact is that some of the seeds couldn't manage to germinate under the same conditions with the others. The reason of this situation can be the level of water I granted, the temperature of the room or any factor that affects the germination of *Phaseolus vulgaris* (bean) and the *Pisum sativum* (Pea) seeds. However as I have chosen two different type of plants, failure of the germination of some of the seeds isn't a big concern as I can still track my results from the others. When the results for both type of seeds are examined, we see that the different type of liquids affect the germination of these seeds in different ways. These ways are that the speed of germination and the percentage of germination as some of the seeds have been affected badly from the conditions resulting them to be decayed. Some of the liquids stimulated the process of germination in the given time but they have also decreased the rate of germination by limiting the volume of water the plant could take.

Yağız Efe MERTOL,18
001129 -0009

Conclusion and Evaluation

Considering my earlier researches, I expected the caffeine containing products to stimulate the process of germination. The material I read about farmers around the world using coffee to stimulate the farming activity made me think it is logical that the potassium and ingredients of coffee can affect the germination process in a positive way. However, as plants don't have a nervous system, caffeine wouldn't be able to affect the seed as it affects the human body.

As I started my experiment, I watered my plants with tea and coffee solutions every day. Both of these solutions have affected the seed coats pretty visibly. One pea and one bean seed have managed to germinate successfully in each of the pots I watered with tea and coffee solutions. When I compare the germination percentages with the pot watered with tap water, I see that the seeds watered with tap water has germinated more successfully than the ones watered with tea and coffee solutions. Mean number of two which is %20 of the peas and mean number of two which is %20 of the beans germinated in the pot with tap water while mean number of one which is of %10 of the peas and mean number of four which is %40 of the beans germinated in both of the pots watered with tea and coffee solutions.

The purpose of this experiment was to discover how daily used caffeine containing products will affect the germination of plant seeds. As I have used solutions containing different concentrations of caffeine to discover their effect on two different types of seeds. Through my trials, I reached two different type of data consisting of the effect of caffeine containing products on the speed of germination of a seed and the effect of caffeine containing products on the accuracy of germination of a seed.

When we examine the effect of caffeine containing products on the speed of germination of a seed, considering the control pot that was watered with tap water, the comparison shows us that while the peas took longer to germinate in the pot watered with tap water then the seeds in the pot watered with coffee solution, beans germinated faster when watered with tap water instead of coffee solution. When the results of tea solution is taken into consideration, it is visible that the seeds that were watered with tap water germinated faster than the seeds that were watered with tea solution. However, this data doesn't look reliable considering the p value I reached from the Anova Test.

If we consider the next parameter, the effect of caffeine containing products on the accuracy of germination of a seed, we have more of a reliable data considering the p value obtained from the Anova test. Both in the pots watered with tea and coffee solution, the accuracy of germination was lower than the accuracy of germination in the control pot. This result gives us a clear idea about the effect of caffeine containing products on the accuracy of germination of a seed.

A few sources of error were possible in this experiment. First of all, as I am watering the pots by hand, I might have not managed to water all the seeds equally. To avoid this error, I probably should use a drip irrigation system to fix this error in my next experiments. In addition, all of the seeds has already had a different germination potential before they are even planted. This is caused by the genetic diversity of plants. To avoid this error, more trials should be done to minimize the amount of error. For example: ten different type of seeds planted on 100 pots.

To reach a result from all of these evaluations, using caffeine containing products that we consume on daily basis to water seeds that are likely to germinate

doesn’t affect this process positively. As I have proven my hypothesis to be wrong, I can see some reasons that can reach to this type of a result. As watering with some other products except water decreases the amount of water the seed can take from outside, the seeds watered with caffeine containing products could have experienced water deficiency. In addition, caffeine is known to cause calcium deficiency in human body when consumed without enough support of calcium containing products, so the amount of caffeine given to the seed could have resulted with calcium deficiency in the seed which seems logical because of the fact that a seed uses calcium while germinating.

When the earlier researches were observed, I expected the Milk and Milk based products to affect the germination process in a positive way. An animal sourced product, milk contains a significant amount of lactose and calcium in it, earning itself a considerable place in the eating habits of human. As calcium is one of the main supporters of bone growth in human, it also has a considerable place in the germination process of a seed. Because of this fact, I believed that milk and other daily used products can stimulate and increase the accuracy of the germination process of a seed. However, some reports I came across in the internet defended the opposite situation so this pushed me to experiment it by myself.

As I started my experiment, I watered my plants with milk and buttermilk solution every day. Both of these products have affected the seed coats pretty visibly, making the seed coats of peas turn to white. Two pea and two bean seeds have managed to germinate successfully in the pot I watered with milk. When I compare the germination percentages with the pot watered with tap water, I see that the seeds watered with tap water has germinated in a pretty similar accuracy and timing. Mean number of two

which is %20 of the peas and mean number of two which is %20 of the beans germinated in the pot with tap water while only mean number of two which is %20 of the peas and mean number of three which is %30 of the beans germinated in the pot watered with milk. However, four pea and three bean seeds have managed to germinate in the pot watered with buttermilk, overrunning all the other experimental. Comparing this result with my control material, pot watered with tap water, we see that the seeds watered with buttermilk has germinated with a higher accuracy than the seeds in the pot that was watered with tap water.

My purpose in this experiment was to discover the effect of milk and milk based daily used products would affect the process of germination of a plant seed. By using two different products, I aimed to find if the milk can have different effects when it is fermented into another product. Looking at my trials on two different type of plant seeds, I have reached two different types of data that can be listed as the effect of milk and milk based daily used products on the speed of germination of a seed and the effect of milk and milk based daily used products on the accuracy of germination of a seed.

To examine the effect of milk and milk based daily used products on the speed of germination of a seed, comparing the data gained through the seeds that were watered with milk and buttermilk with the data gained through the seeds in the control pot gives us the evaluation needed. The comparison shows us that while the pea seeds in the pot watered with milk germinated faster than the ones germinated in the pot watered with tap water, the opposite situation was experienced for the bean seeds. The data taken through the seeds that were watered with buttermilk was pretty similar with the data collected from the control pot resulting with an evaluation that isn’t

powerful. In addition, the p value gained through the Anova test of this data is higher than it should be showing us that this parameter isn't reliable.

As I have researched earlier, there wasn't a significant amount of experiments made about the effect of sugar solutions and sugar containing liquids on the germination process of a seed. Through the background I gained from these limited amount of experiments and the information that the seed uses the food stored in the seed coat to germinate, I produced the hypothesis of the seeds will germinate with better accuracy when watered with sugar solution or a sugar containing product.

To experiment this situation, I watered my plants with sugar solution and juice every day. The pot I watered with juice got visibly moldy. One pea and four bean seeds have managed to germinate successfully in the pot I watered with sugar solution. When I compare the germination percentages with the pot watered with tap water, I see that the seeds watered sugar solution have shown some inconsistent results. Mean number of two which is %20 of the peas and mean number of one which is %20 of the beans germinated in the pot with tap water while only %10 of the peas and Mean number of four which is %40 of the beans germinated in the pot watered with sugar solution. Also, one pea and four bean seeds have managed to germinate in the pot watered with juice. Comparing this result with my control material, pot watered with tap water, we see that the bean seeds watered with sugar solutions and sugar containing products have managed to germinate better than the pot watered with tap water, while the pea seeds couldn't.

To examine the effect of sugar solution and sugar based daily used products on the speed of germination of a seed, comparing the data gained through the seeds that were watered with sugar solution and juice with the data gained through the seeds in

the pot watered with tap water gives us the evaluation needed. The comparison shows us that while the bean seeds in the pot watered with sugar solution and juice germinated faster than the ones germinated in the pot watered with tap water, the opposite situation was experienced for the pea seeds. The data taken through the seeds that were watered with sugar solution was pretty similar with the data collected from the pot watered with juice. In addition, the p value gained through the Anova test of this data is higher than it should be showing us that this parameter isn’t reliable.

References

1. Raven, Peter H.; Ray F. Evert; Susan E. Eichhorn (2005). Biology of Plants, 7th Edition. New York: W.H. Freeman and Company Publishers. pp. 504–508.ISBN 0-7167-1007-2.
2. Jump up^ Siegel, S. M.; Rosen, L. A. (1962). "Effects of Reduced Oxygen Tension on Germination and Seedling Growth". Physiologia Plantarum 15 (3): 437–444. doi:10.1111/j.1399-3054.1962.tb08047.x.
3. Jump up^ Derek Bewley, J.; Black, Michael; Halmer, Peter (2006). The encyclopedia of seeds: science, technology and uses Cabi Series. CABI. p. 203. ISBN 0-85199-723-6. Retrieved2009-08-28.
4. Jump up^ Sadhu, M.K. (1989). Plant propagation. New Age International. p. 61. ISBN 978-81-224-0065-6.
5. Jump up^ Martin FW (1972). "In Vitro Measurement of Pollen Tube Growth Inhibition". Plant Physiol 49 (6): 924–925. doi:10.1104/pp.49.6.924. PMC 366081. PMID 16658085.
6. Jump up^ Pfahler PL (1981). "In vitro germination characteristics of maize pollen to detect biological activity of environmental pollutants". Environ. Health Perspect. 37: 125–32.doi:10.2307/3429260. JSTOR 3429260. PMC 1568653. PMID 7460877.
7. Jump up^ Takayama S, Isogai A (2005). "Self-incompatibility in plants". Annu Rev Plant Biol 56 (1): 467–89. doi:10.1146/annurev.arplant.56.032604.144249. PMID 15862104.
8. Jump up^ Roca, M.; Davide, L.C.; Davide, L.M.; Mendes-Costa, M.C.; Schwan, R.F.; Wheals, A. (2004). "Conidial anastomoses fusions between Colletotrichum species". Mycological Research 108 (11): 1320–1326. doi:10.1017/S0953756204000838.
9. Jump up^ Roca, M.G.; Arlt, J.; Jeffree, C.E.; Read, N.D. (2005). "Cell biology of conidial anastomosis tubes in Neurospora crassa". Eukaryotic Cell 4 (5): 911–919.
10. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1276408/
11. http://plantsinmotion.bio.indiana.edu/plantmotion/earlygrowth/germination/germ.html
12. https://prezi.com/vsfx4_5ghvpa/how-does-adding-sugar-to-the-soil-affect-the-plants-germination-and-growth/
13. http://www.madsci.org/posts/archives/2005-02/1107918751.Bt.r.html
14. http://www.all-science-fair-projects.com/print_project_1240_50