TED ANKARA COLLEGE
IB PROGRAM
BIOLOGY EXTENDED ESSAY

Investigation of the optimum irrigation level on the development (growth) and germination of common wheat (*Triticum aestivum*)

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Abstract

The main aim of the experiment was to found the optimum irrigation level for the germination success and growth of the common wheat seeds. Use of common wheat is necessary basic nutrition which is carbohydrates. I wanted to found a method that consumes small amount of water and still will be able to produce healthy plant. I designed a schedule that really consumes small amount of water and still was able to harvest. My reason for investigating the optimum irrigation level is that I found that some of the LEDCs has a very high global hunger index value. Also these LEDCs has significantly low wheat production and I believed as I thought about my experiment I might help this production rate as I found a optimum irrigation level efficient for the growth of common wheat.

I mostly interviewed with my aunt Zehra Gözalan, who is an agricultural architect as I need information about the common wheat seeds behaviors and properties. She helped a lot as I tried to found optimum controlled variables and different irrigation levels.

I resulted that the common wheat seeds can be produced with the low usage of water so that drought LEDCs can also produce common wheat seeds. However I resulted in two different aspects. First, average number of germinated seeds is greatest for 40ml irrigation level. Secondly, average growth on germinated seeds in centimeters is greatest for 30ml irrigation level.

Table of Contents

Introduction

In today's world, starvation is one of the major problems. In lots of countries people are starving to death. I researched about this matter and I saw less economically developed countries (LEDCs) have more global hunger index. For example Burundi, Eritrea and Comoros, these countries have the highest global hunger index. Most of the LEDCs such as the examples have high global hunger index due to the low agricultural production rate. As Burundi, Eritrea and Comoros have the highest rate of global hunger index they also have the lowest wheat production. This cannot be a coincidence, because the wheat is the main part of human's food chain, lack of it can obviously cause starvation. I felt sad and responsible as the youth of this generation about this situation. I believe, I could encourage the people of the LEDCs to farm and produce something. Then I decided to investigate the optimum irrigation level that favors common wheat production at most and I believe irrigation is the most effective factor for the production. However as I investigate the effect of irrigation I must control other variables. My focus on the experiment was designing it as much as simple as I wonder how

Common wheat is also one of the easiest agricultural product, so why we are giving a pass to the humans starving. We, as sophisticated people can teach and support people the production of the common wheat. It is highly affordable and common wheat can be germinated at basic structured greenhouses if the environment is divergent to the common wheat.

“Bread wheat (common wheat) is more widely cultivated than any other crop. Bread wheat is cultivated in every continent except Antarctica. Although it is possible to grow bread in a wide variety of soil types and climates, it is more successful in dry to sub-humid areas with seasonal rainfall of 250 – 750 mm. Wheat landraces are varieties that have been developed by farmers over many years and through natural and human selection have become adapted to local environmental conditions and management practices. These distinct plant populations are named and maintained by farmers who often rely on them to fulfill their specific local needs and are valuable source of biodiversity for possible use in breeding programs.”

“Today, wheat is grown on more land area than any other commercial crop and continues to be the most important food grain source for humans. Its production leads all crops, including rice, maize and potatoes. The optimum growing temperature is about 25°C, with minimum and maximum growth temperatures of 3° to 4°C and 30° to 32°C, respectively (Briggle, 1980). Wheat is adapted to a broad range of moisture conditions from xerophytic to littoral. Although about three-fourths of the land area where wheat is grown receives an average of between 375 and 875 mm of annual precipitation, it can be grown in most locations where precipitation ranges from 250 to 1 750 mm (Leonard and Martin, 1963). Optimal production requires an adequate source of moisture availability during the growing season; however, too much precipitation can lead to yield losses from disease and root problems. Cultivars of widely differing pedigree are grown under varied conditions of soil and climate and show wide trait variations. Although wheat is being harvested somewhere in the world in any given month, harvest in the temperate zones occurs between April and September in the Northern Hemisphere and between October and January in the Southern Hemisphere (Percival, 1921)."

I choose to investigate and transfer the optimum irrigation level and regulated plan of irrigations as a first step for myself. In this experiment I will try to find the perfect irrigation plan that LEDCs can accomplish. In response my research question occurred as; ***'what is the most proper irrigation schedule for the most efficient germination and development of the common wheat?***

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Hypothesis and Research

My research in order to decide different irrigation levels occurred as interviewing with an expert landscape architect, Zehra Gözalan, and I appreciate her assistance very much. I acknowledged that the time common wheat requires to leave the greenhouse averagely 12 days and 21-28 for total growth and maturity. Greenhouse remains the moisture for the plants so after they left the greenhouse ambient irrigation periods must be shorter. Also because the bodies of the plants will be bigger the irrigation period must be shorter. Mrs. Gözalan recommended the irrigation levels as 10,20,30,40 and 50 milliliters. As I learned the common wheat more I created my hypothesis. My hypothesis is: *common wheat seeds* *germinate most successful at 30 milliliters irrigation level but growth will be greater at 50 milliliters irrigation level.*

Method Development

I preferred 5 identical rectangle containers, which have plastic caps that create greenhouse effect. The caps of the containers must be removed after the plants reach a specific height greater than the cap height. The biggest issue was the growth would be different for each irrigation levels, but the caps must be removed at the same time in order to remain the greenhouse effect as a constant variable. Specifically, for example 10 - ml irrigated seeds would take more time to reach apical growth period than 30 ml - irrigated seeds so at the moment 30 ml irrigated seed reach apical growth period the cap of the container must be removed. The systematic error is that 10 ml-irrigated seeds would still need greenhouse effect created by the cap of the container but it also needed to be removed since the greenhouse effect is constant variable. I estimated the removal time of the caps as the 10^{th} day of the experiment period.

My irrigation plan was occurred as first irrigation at planting day, 5 further irrigations with 3 – day period and 3 more irrigations with 2-day period. Finally my total irrigation number occurred as total 8 irrigations over exact 20 – day. This irrigation schedule is informed me from Zehra Gözalan which is the standard procedure applied on her seed germination greenhouse. However this schedule designed for the germination of the flowering plants but Zehra Gözalan also informed me that the difference is insignificantly small. I decided to collect data at 27^{th} day because I wanted to observe how the seeds response not to be irrigated for a week after a scheduled irrigation period. Hopefully I would be able to decide which trials develop endurance better.

The planting order was very important because of the growth of the common wheat seeds are great. I designed 3 rows with 4 seeds per trial spacing, so that seeds would be nicely ordered. This design would allow seed growth in order. This design can be found on **Figure 1.**

Common wheat seeds are removed after germination period and planted on soil fields at wheat production factories, this is regular procedure. Unfortunately my experimenting couldn't follow this procedure. This may result a systematic error; sufficient soil depth which may cause unhealthy seed germination and slower apical growth. I decided to observe firstly growth and secondly germination success.

The dependent variable of my experiment is the germination rate and the average growth in centimeters of the common wheat seeds. The independent variable is the irrigation level of the seeds. I created irrigation schedule as presented in the method and I controlled the irrigation precision using syringe so I would be able to irrigate seeds gently and at the exact volume as I needed. I decided to place the seeds 21.5 °C as recommended by Zehra Gözalan. It was trustworthy to control the temperature because my household heating system preserves the temperature preferred. I used the system to lock the temperature at 21.5 °C for 27 days. The pressure was also a controlled variable, which however have insignificant effect on the seeds. The moisture of the air was in the favor of the experiment because the air in Ankara is very dry and I was happy with the low moisture in the air as a controlled variable for my experiment. Because for LEDCs, not all the ecosytems have a moist air due to the large amount of rainfall per year. For example Eritrea, which I have mentioned in my introduction, has a drought habitat and I would like to create a poor habitat as possible, because the main focus of my experiment is the LEDCs.

Material list

1. Five identical containers ($55 \times 14 \times 6\ dimension\ in\ cm$)
2. Light and air transparent caps, which are suitable to the containers base.
3. 300 common wheat seeds (conserve some extra seeds because some of them might be unhealthy)
4. Plastic waterproof plates, which can function as a separator.
5. 3 kg of peat.
6. Tap water.
7. 50 ml syringe.
8. Ruler
9. Toothpick

Design

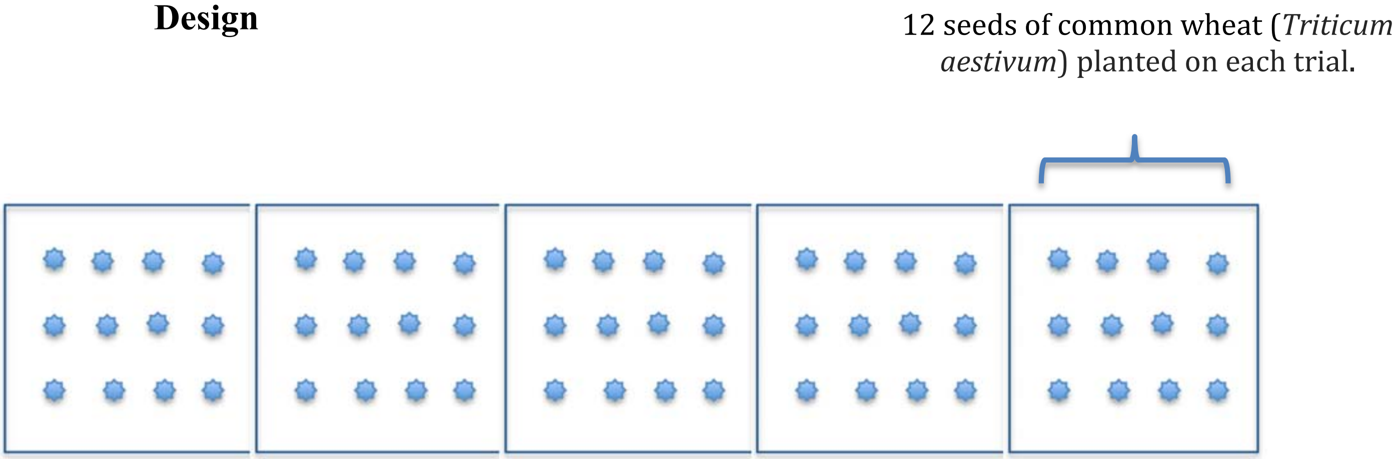

Figure 1. Presents the common wheat seeds planting regulation. (Eagle View presentation of the containers.)

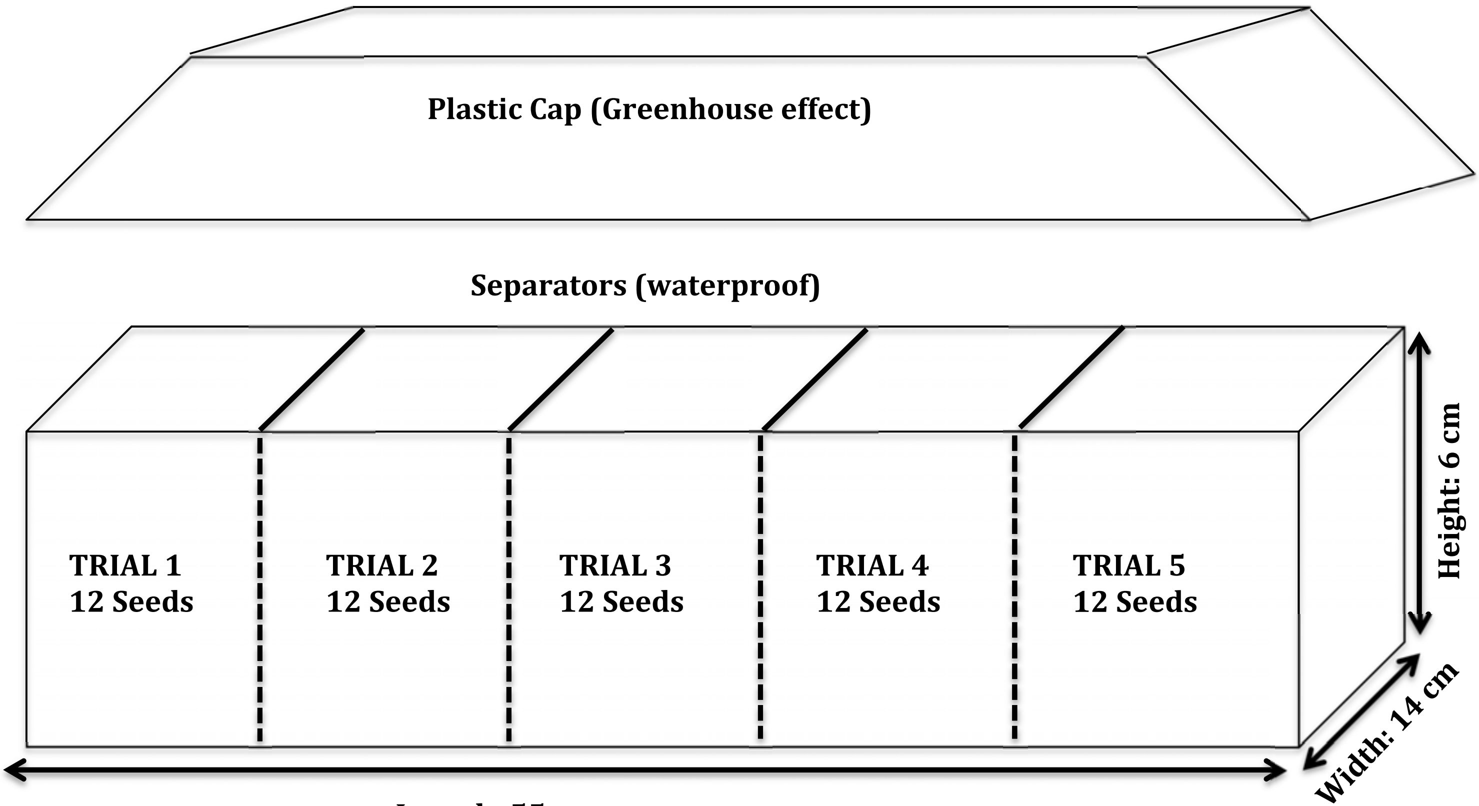

Figure 2. Presents the trial order of a specific irrigation level container. Labeled as 20 mL for example in the figure.

Method

1. Place any soil type preferred up to 5 cm into the all five containers. 5 cm is excessive for germination but because in this experiment growth of the seeds is observed, 5 cm of soil is needed for the roots of the growing plants. (Peat is used as soil in my experiment due to its lightweight structure.)
2. Using a ruler, flatten the surface of the all containers.
3. Place separators after every 11 cm in the containers as they split and stuck into soil. Eventually after you repeat the process for every containers will be divided into 5 equal surface areas for each representing a trial as seen in the **Figure 2.**
4. Identify healthy seeds as much as possible and separate them.
5. Dig small holes for the seeds with your finger.
6. Place seeds in to the halls.
7. Again smoothen the surface with ruler in order to close the halls with peat.
8. Compress gently the surface with your palms and randomly stick a toothpick into the surface in order to open airway. (This method recommended by Zehra Gözalan in order to create a healthy and most importantly stable environment for seeds)
9. Then start irrigation as scheduled below: (pull water to the syringe in the specific irrigation level and then gently disturb water to the surface of the trials)

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1. First Irrigation	2	3	4. Second Irrigation	5	6	7. Third Irrigation
8	9	10. Fourth Irrigation	11	12	13. Fifth Irrigation	14
15	16. Sixth Irrigation	17	18. Seventh Irrigation	19	20. Eighth Irrigation	21
22	23	24	25	26	27. Data Collection	

10. Remove the caps at the 10th day.

11. Gently disperse the soil around the root of the seeds so that it will be safer and easier to dislocate the seeds from the soil.

12. Lay down the stems of the seeds to the floor then measure with a ruler the height of them.

Data Collecting

	50 ml Irrigated Seeds				
	Trial 1	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**
Seed 1	**27**	**21**	**19**	**25**	**24**
Seed 2	**19**	**23**	**30**	**21**	**21**
Seed 3	**17**	**18**	**24**	**16**	**23**
Seed 4	**20**	**25**	**20**	**23**	**18**
Seed 5	**24**	**Death**	**23**	**21**	**23**
Seed 6	**24**	**Death**	**20**	**Death**	**Death**
Seed 7	**19**	**Death**	**15,5**	**Death**	**Death**
Seed 8	**17**	**Death**	**15,5**	**Death**	**Death**
Seed 9	**Death**	**Death**	**Death**	**Death**	**Death**
Seed 10	**Death**	**Death**	**Death**	**Death**	**Death**
Seed 11	**Death**	**Death**	**Death**	**Death**	**Death**
Seed 12	**Death**	**Death**	**Death**	**Death**	**Death**

	40 ml Irrigated Seeds				
	Trial 1	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**
Seed 1	17	22	21	17	23
Seed 2	21	16	23	27	22
Seed 3	20	23	30	22	16
Seed 4	21	23	28	18	21
Seed 5	19	20	21	18	20
Seed 6	20	18	19	21	12
Seed 7	21	19	23	19	19
Seed 8	18	22	24	36	18
Seed 9	22	Death	21	19	28
Seed 10	21	Death	25	22	9
Seed 11	16	Death	Death	Death	20
Seed 12	Death	Death	Death	Death	Death

	30 ml Irrigated Seeds				
	Trial 1	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**
Seed 1	21	19	20	24	23
Seed 2	24	25	24	28	23
Seed 3	17	27	22	27	27
Seed 4	29	26	22	20	21
Seed 5	20	28	26	24	25
Seed 6	26	23	14	21	12
Seed 7	22	23	25	30	25
Seed 8	27	23	22	22	22
Seed 9	21	26	Death	18	23
Seed 10	22	24	Death	Death	25
Seed 11	28	Death	Death	Death	29
Seed 12	Death	Death	Death	Death	Death

	20 ml Irrigated Seeds				
	Trial 1	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**
Seed 1	18	17	24	25	23
Seed 2	23	21	22	23	19
Seed 3	21	22	19	20	19
Seed 4	20	22	20	19	28
Seed 5	20	30	24	27	18
Seed 6	17	25	19	20	16
Seed 7	20	Death	29	19	Death
Seed 8	Death	Death	26	25	Death
Seed 9	Death	Death	Death	13	Death
Seed 10	Death	Death	Death	17	Death
Seed 11	Death	Death	Death	Death	Death
Seed 12	Death	Death	Death	Death	Death

	10 ml Irrigated Seeds				
	Trial 1	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**
Seed 1	Death	Death	Death	Death	Death
Seed 2	Death	Death	Death	Death	Death
Seed 3	Death	Death	Death	Death	Death
Seed 4	Death	Death	Death	Death	Death
Seed 5	Death	Death	Death	Death	Death
Seed 6	Death	Death	Death	Death	Death
Seed 7	Death	Death	Death	Death	Death
Seed 8	Death	Death	Death	Death	Death
Seed 9	Death	Death	Death	Death	Death
Seed 10	Death	Death	Death	Death	Death
Seed 11	Death	Death	Death	Death	Death
Seed 12	Death	Death	Death	Death	Death

The five tables above presents the raw data of the experiment after 27 days of procedure. The data presents the growth in centimeters for all the 300 seeds planted and irrigated with the specific irrigation values. The irrigation values are labeled at the top of the values and the values labeled as ‘death’ indicates that the seeds were unable to successfully develop. The specific observation that I have made for the ‘death’ seeds is that the colors of the body’s of the seeds were turn into yellow. I asked this result to the Zehra Gözalan and the explanation made was the chlorophyll pigments were insufficiently produced for the seeds due to lack of water. The specific water irrigation level was so insufficient that the seeds were unable to photosynthesis. I observed the thin stem of the seeds develop until the second week of experiment then they started to lose color and bend down, so the seeds do have developed but then they ‘started dormancy’ period as explained by Zehra Gözalan. The seeds stopped metabolic activity and isolated it to germinate, as it will found a better medium. At the greenhouses farmers collect the seeds of these types of plants seeds because the plant itself would not be nutrition. This is the reason why I labeled ‘death’ and entered 0 cm growth for my data processing.

I calculated the percentage rate of germination succession in order to comment on the results clearly. I would like to give an example to this calculation with 40 ml irrigation level trials:

1. Result the number of seeds germinated for all trials:

Trial 1	11
Trial 2	8
Trial 3	10
Trial 4	10
Trial 5	11

2. Evaluate the mean value of the five data, which is equal to ‘10’ for 40 ml irrigated seeds.
3. Then apply the mean value on the formula: $\frac{Mean\ Value}{12} \times 100 \rightarrow \frac{10}{12} \times 100 = 83.28\%$

		Average length of only germinated seeds ($\pm 0.1\ cm$)	Average length of all seeds ($\pm 0.1\ cm$)	Number of successful germination	Germination succession percentage
50 ml Irrigated Seeds	Trial 1	21.43	13.64	8.00	66.60%
	Trial 2	21.75	7.25	4.00	33.30%
	Trial 3	23.20	13.60	8.00	66.60%
	Trial 4	23.78	8.83	5.00	41.60%
	Trial 5	21.80	9.08	5.00	41.60%
	Total Average for Trials	**22.39**	**10.48**	**6.00**	**49.94%**
40 ml Irrigated Seeds	Trial 1	19.64	18.00	11.00	91.60%
	Trial 2	20.38	13.58	8.00	66.60%
	Trial 3	23.78	19.58	10.00	83.30%
	Trial 4	21.90	18.25	10.00	83.30%
	Trial 5	18.91	17.33	11.00	91.60%
	Total Average for Trials	**20.92**	**17.35**	**10.00**	**83.28%**
30 ml Irrigated Seeds	Trial 1	23.36	21.42	11.00	91.60%
	Trial 2	24.40	20.33	10.00	83.30%
	Trial 3	21.88	14.58	8.00	66.60%
	Trial 4	23.78	17.83	9.00	75%
	Trial 5	23.18	23.18	11.00	91.60%
	Total Average for Trials	**23.32**	**19.47**	**9.80**	**81.62%**
20 ml Irrigated Seeds	Trial 1	19.86	11.58	7.00	58.30%
	Trial 2	22.83	11.42	6.00	50%
	Trial 3	22.88	15.25	8.00	66.60%
	Trial 4	20.33	17.33	10.00	83.30%
	Trial 5	20.50	10.25	6.00	50%
	Total Average for Trials	**21.28**	**13.17**	**7.40**	**61.64%**
10 ml Irrigated Seeds	Trial 1	0.00	0.00	0.00	0%
	Trial 2	0.00	0.00	0.00	0%
	Trial 3	0.00	0.00	0.00	0%
	Trial 4	0.00	0.00	0.00	0%
	Trial 5	0.00	0.00	0.00	0%
	Total Average for Trials	**0.00**	**0.00**	**0.00**	**0%**

Table 1. Presents the average growth of only germinated seeds / all the seeds and the number / percentage of the germinated seeds.

Evaluation and Conclusion

First of all I would like to investigate the average growth of the only germinated seeds. This calculation made as I only take the mean growth values of the germinated seeds. For example, the **Table 1**. presents for the 50 ml irrigation level, only 6 seeds of 12 successfully germinated and total average growth of the 6 seeds is 22.39. This calculation could not lead me into a detailed success of the germination of seeds. As presented in the **Table 1.** the average growth of successfully germinated seeds is similar in numbers for irrigation levels except 10 ml irrigation level (10 ml irrigation level has a specific situation that I will explain further in my report). As a result seeds that was able to germinate, reached similar heights, the major difference was due to the succession of germination.

The **Table 1.** presents the different ranges of average growth of all the seeds. This calculation made as taking the mean growth of all the seeds, germinated or not. This calculation lead me to more clear ideas about the experiment because it presents the efficiency of the germination and growth of the seeds, because as we apply the results to the fields, we will be able to decide which irrigation level would have more efficient harvest.

The optimum irrigation level is presented in the Table 1. as 30 ml. Total average of growth of for 5 trials and 60 seeds, is the maximum for 30 ml irrigation level with the value of 19.47 cm. The value of the growth of the seeds increased as the irrigation levels increase until 30 ml irrigation level, then the value decreased significantly. My hypothesis was wrong, I assumed that the growth would be greatest for the 50 ml irrigation level.

For the 40 ml irrigation level, Table 1. presents that the average growth value is 17.35 which is close to the 30 ml irrigation level results, however the average number of successfully germinated seeds of 40 ml irrigation level is maximum in all irrigation levels and also greater then the 30 ml irrigation level values. The positive outcome of the 40 ml irrigation at the end of the harvest, number of successfully germinated and growth healthy seeds would be greater in number rather then 30 ml irrigated seeds. However 40 ml irrigation level requires 10 ml more water for every irrigation dates, and the average number of successful germinated seeds of 30 ml irrigation level is insignificantly small than the 40 ml irrigation level. My humble opinion is the 30 ml irrigation level is more efficient especially for LEDCs due to its acceptable requirement of water and its production of successfully germinated mature seeds.

As I return back to my hypothesis, I assumed that the germination percentage would be greatest for the 30 ml irrigation level. However, even if it is close to the 40 ml irrigated seeds germination percentage my hypothesis is wrong. The small difference between 30 and 40 ml irrigation levels may result a bigger difference of harvest amount for a large agriculture field.

The reason why the 10 ml irrigated seeds suffered death is because of the drought period after the final irrigation. I wanted to observe which specific irrigation level would be able to perform survive. All the 10 ml irrigated seeds could not able to survive 7-day period of drought. I experimented this because I would like to found the minimum irrigation level for a water-poor country or LEDCs. I believe I resulted 10 ml irrigation level is not sufficient for the germination of the common wheat seeds. Although I investigated survival period, other irrigation levels chosen for the experiment are already small volumes and the germination is highly water efficient if the irrigation is scheduled properly.

The Statistical Investigation of The Experiment

ANOVA

Source of Variation	*d.f.*	*SS*	*MS*	*F*	***P - level***	*F crit*	*Omega Sqr.*
Between Groups	3	246.08362	82.02787	9.65667	**0.00071**	3.23887	0.56493
Within Groups		16	135.91088	8.49443			
Total	19	381.9945					

Descriptive Statistics

Groups	*Sample size*	*Sum*	*Mean*	*Variance*
20 ml	5	65.83	13.166	8.93723
30 ml	5	97.34	19.468	11.22697
40 ml	5	86.74	17.348	5.10467
50 ml	5	52.4	10.48	8.70885
Total	20		15.1155	20.10497

The statistics tables presented above are the ANOVA application on the data of the average length of all seeds from the **Table 1.** The value I focused mostly was the **p-level.** Because it was the representation of the significance and expressiveness of my experiment's results. The value of the p-level is below 0.05, which indicates my results are statistically significant for different irrigation levels. However the p – level could have been much smaller with more significant results, so I would like to discuss the possible errors that downgraded my results.

The major systematic error is caused due to the waterproof separators. Separators used to create private mediums for each 25 sectors consisting 12 seeds. However I did not stabilize the separators to the ground of the container. This firstly caused water to flow underneath the separator to the denser soil, so the water did not irrigated fairly to all the trials. The second negative outcome of this is the competition between the seeds. The area separated for 12 seeds became smaller as they grew up. The result was the competition of rooting to more soil, because the soil I used was highly rich with minerals and the seeds feel the need more to it as their dry weight increased. I found at the end of experiment some roots suffocating other seed's roots, so the seeds defeated by others reached shorter heights for the same irrigation level. The possible and the easiest solution is to stabilize the separators to the container with silicon gun but this solution might be intoxicating. However 25 completely separated containers with the same volume might be used as a surface are but the containers must be spaced enough to prevent the competition in a container.

I mentioned before that the soil I used is highly rich with minerals and super light soil that seeds can easily germinate. It is expensive and quality soil type produced specially for germination, so I believe my choice is not suitable for this experiment. Because it is hard to obtain this type of soil for LEDCs. I believe a drought soil dig out from my garden would be more realistic.

I first explained about the error caused by the cap of the container at my method development. The assumption I made was, as different irrigation levels lead seeds to be apically grown differently, so as one seed reach the cap length another would not. In order to remain greenhouse effect preserve as a constant variable, I preferred 10-day period as a constant time for the removal of the cap. However, this method was a poor solution because as I removed the cap I observed 10 ml, 20 ml, 50 ml, irrigated seeds were still in need of greenhouse effect; their stems were still immature. I believe a better design for this problem is to remove cap after seeds of a specific irrigation level averagely reaches the cap height.

I evaluated the literature and compared it to my experiment. I have found that the independent variables of the literature experiment investigated differently than me. Besides scheduling irrigation levels using ml values, the experiments were made by altering the kg/m^2 values. This method needs to be applied on further experiments as it is in the literature. The method of applying this independent variable is to weight the water as planning the kg/m^2 irrigation schedules.

References

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