Biology Internal Assessment

To what extent do various types of water affect the growth rate of Mung seeds hydroponically grown ?

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INTRODUCTION

With the spread of COVID-19, the interaction between people has become limited because of social distancing policies, quarantines and lockdowns have become more common, and in some places, extended. Thus, being directly affected by stay-at-home orders, I searched for things to occupy my time. Especially in the middle of the quarantine, I found myself restless, and as a nature-lover, unable to interact with the natural environment. This led me to the idea of growing things myself. Not knowing much about how plants are grown, I was led to various explanations of plant-raising methods. Obviously, soil based methods are a common method; yet, I also found another type of plant cultivation in hydroponics, a water-based method. This way of growing plants led me to consider research more on how it is done. Much of the literature says that the nutrient-rich solution is pivotal to the success of growing plants in this manner. With claims like these, I wondered if truly the type of water was significant enough to affect the rate of growth of a plant. To put a finer point on things I thus asked, “To what extent do various types of water affect the growth rate of hydroponically grown Mung Seeds?”

When it comes to the plant propagation, there are different techniques that are used so that plants can grow. To be specific, the most common way to grow plants is to grow them in soil. Although there are other factors that affect the growth rate of plants, soil is one of the essential factors to consider. Also, it is the easiest way to plant since soil provides efficient nutrients needed for plant growth (why are soil important?; ISRIC.org). However, soil based planting is not the only method available as a new form of planting has become popular: hydroponics. According to Chris Woodford, hydroponics refers to the method of growing plants not in soil but in water (2020). The reason why plants grow hydroponically is that when the roots of the plants are dipped into the nutrient-rich water, their roots can directly access the needed nutrients, and thus, this helps plants be nourished (Woodard. J, 2019).

Given these different ways to grow plants, soil and hydroponic cultivation of plants show different rates of growth. Specifically, Evan Gillespie mentioned that plants grown hydroponically tend to show faster growth compared to plants grown in soil. This is because oxygen and nutrients are directly delivered to roots where they can use these nutrients for their own growth. In contrast, when plants are put into the soil, there can be other obstacles and distractions that plants might experience to obtain nutrients. With that, it is clear hydroponic is a much more effective way to cultivate plants.

However, considering the fact that not all types of solution provide the same condition and the nutrients for plants, this research decided to further investigate how different types of water may affect plant growth rate. In this study, three types of water were used; to start, a nutrient solution of tap water mixed with Plant Partners Type A Hydroponic Solution. Aside from tap water, this solution consists of major chemical components like 0.01% of nickel, 2% of nitrogen, 2% of calcium, 0.05% of ion, 0.1% of chromium, and 3.5% of potassium. Not only were those elements found but also like amino acid and glutamic acid were included (Plant partners, 2020). The second type of water tested was pure tap water from Seoul City, South Korea; tap water contains traces of several minerals such as Calcium, Magnesium, Sodium, and Potassium (Seoul Metropolitan Government, 2019). In addition to these minerals, Seoul tap water also contains other materials of chemicals like iron, copper, and geosmin which affect the taste of the water (Seoul Metropolitan Government, 2019). The third and final type of water tested was mineral water from “Samdasoo” which contains natural minerals such as calcium, potassium, magnesium, vanadium, and silica which are all considered to have positive effects on human health (Kim. YS, 2020).

Hypotheses

Based on the varying contents of these three types of water, this paper poses an alternative and null hypothesis. For alternative hypotheses, the mung seeds in the tap water mixed with hydroponic solution will have the fastest growth rate, while for the null hypothesis, the mung seed in all types of

solutions will have the similar growth rate. To determine the accuracy of either of these hypotheses, an experimental design was set up involving different variables summarized in the table that follows:

Variables

Table 1. Control, Dependent, and Independent variables of the paper

Variables	
Control variables	Temperature, Type of Container, Seed kind, Growth period (The time when the seeds were put into the water), and Quantities of water
Dependent variables	The height of the plant
Independent variables	Type of water

Materials & Apparatus

- Mung seeds
- Beaker
- Tap water
- Nutrient solution
- Mineral water (Samdasoo)
- Ruler
- 15 plastic cups with cover
- Clean Wrap
- Sponge
- Cutter Knife
- Marker
- Pinset

Methodology

In the experiment, a sponge is cut into 15 cubes with a length and width of 3 cm. The sponge serves as the medium in which seeds are placed to absorb water. These sponges deliver the sufficient water and whatever nutrients it contains to the seeds. After cutting the sponge, those pieces of sponge cubes are scored to create a canal in which secure the mung seeds. Then, three types of water (tap water with hydroponic solution, tap water, and mineral water) are prepared. To prepare tap water with hydroponic solution, mix 0.625ml of the hydroponic solution for every 250ml of tap water. The 0.625ml

of hydroponic solution is calculated based on the recommended 50ml ratio to 20L of water. From here, the same quantities of water for all three types being tested must be 250ml since the plastic cup is only limited to 250 ml. Thus, 250ml of water will be equally distributed to 15 plastic cups so that there are 5 cups for each type of water. Once the three types of water and the sponges are prepared, 3 mung seeds per container are planted in each plastic cup then sealed with a clean wrap with holes to ensure the stable temperature of 23° since the experiment area can only maintain the temperature of 23°. Also, the purpose of the holes is to ensure that there is a circulation of air in the plastic cup.

After setting up the hydroponics model, record their growth rates by measuring the height of the plants in all types of solution. The data collection starts once the seeds germinate. The data is also gathered every 12 hours for 3 days to see the difference of the height of the plants. Data gathering is done for 3 days because the first 3 days are a significant period for growth of Mung seeds (Reddy. J, 2019). With the collected raw data, the growth rate is calculated using the formula:

$$\{(Final\ Height\ -\ Previous\ Height)\ \div\ Previous\ Height)\}\times\ 100$$

These results are then subjected to a statistical Anova test to see the relationship between the types of solution and the growth rate of the plants. Along with the statistical evidence, graphs are also included to further analyze the data.

Safety and Ethical considerations

In this lab activity, there are several things to be mindful of. First, since the hydroponic water solution includes certain chemicals, it is important to be very careful in handling this solution to avoid unnecessary exposure to it in any way. Beyond careful handling, considering the fact that this solution is a chemical based liquid, ensure that the disposal of the solution is accomplished properly as well. In order to dispose of the solution properly, the solution is mixed with the regular tap water to dilute its

nutrient content after which the solution is poured into a closed drainage disposal system like a kitchen or bathroom drain (Gaiaca, 2020).

Results and Discussion

Table 2. The average height and the standard deviation of the Mung plants with ±0.05 uncertainties starting from day 1 to day 3

AVERAGE	Tap water with hydroponic solution	Tap water	Mineral water
(cm)	±0.05	±0.05	±0.05
Day 1	0.14	0.08	0.14
Day 1.5	0.34	0.22	0.28
Day 2	0.52	0.38	0.46
Day 2.5	0.7	0.52	0.6
Day 3	0.86	0.62	0.7
Standard Deviation	0.2848157299	0.2188149903	0.2286482014

Table 3. Height and the growth rates of the Mung plants of 5 trials with ±0.05 uncertainties (Tap water with hydroponic solution).

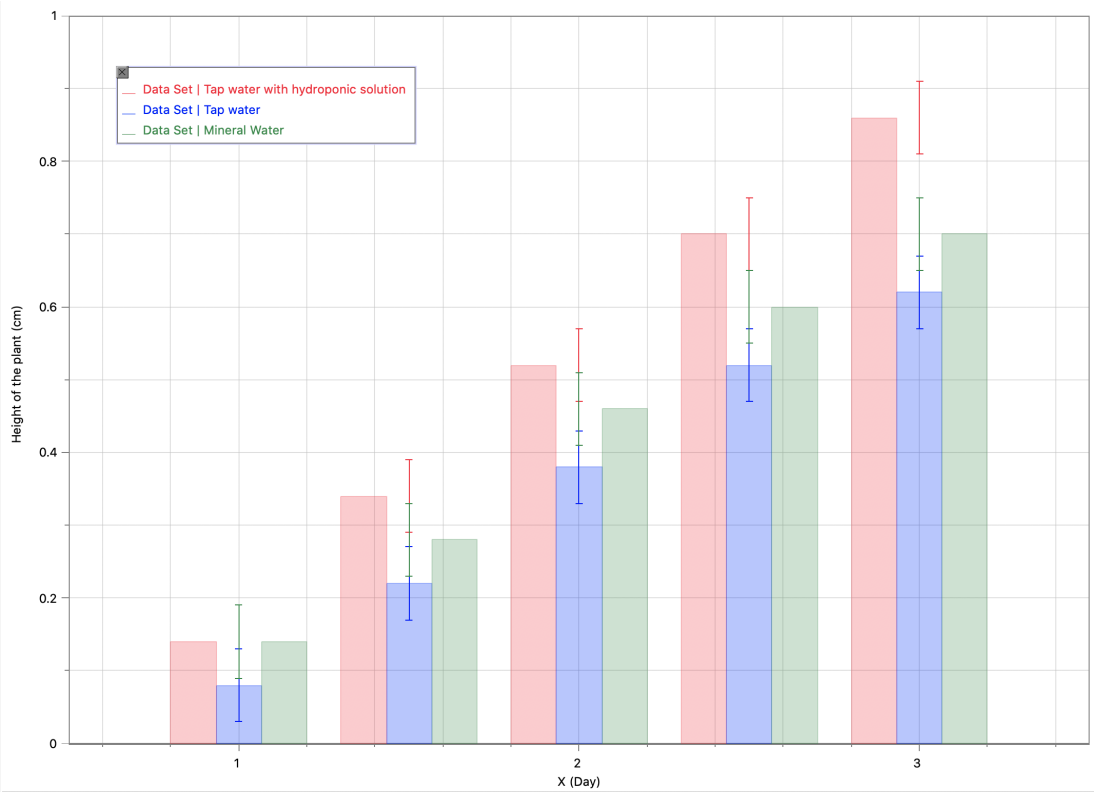
(cm)	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average	Growth rate
Day 1	0.2	0.1	0	0.2	0.2	0.1	
Day 1.5	0.4	0.4	0.2	0.3	0.4	0.3	200%
Day 2	0.5	0.7	0.3	0.6	0.5	0.5	67%
Day 2.5	0.7	0.8	0.5	0.8	0.7	0.7	40%
Day 3	0.9	1	0.6	1	0.8	0.9	29%
The average growth rate							**84%**

Table 4. Height and growth rates of the Mung plants of 5 trials with ±0.05 uncertainties (Tap water).

(cm)	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average	Growth rate
Day 1	0.1	0.0	0.2	0.1	0.0	0.1	
Day 1.5	0.2	0.1	0.4	0.3	0.1	0.2	100%
Day 2	0.3	0.2	0.5	0.6	0.3	0.4	100%
Day 2.5	0.5	0.4	0.6	0.7	0.4	0.5	40%
Day 3	0.6	0.5	0.7	0.8	0.5	0.6	20%
The average growth rate							**65%**

Table 5. Height and growth rates of the Mung plants of 5 trials with ±0.05 uncertainties (Mineral Water).

(cm)	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average	Growth rate
Day 1	0.2	0.1	0.2	0.1	0.1	0.1	
Day 1.5	0.4	0.2	0.3	0.3	0.2	0.3	200%
Day 2	0.6	0.4	0.5	0.4	0.4	0.5	67%
Day 2.5	0.7	0.5	0.7	0.5	0.6	0.6	20%
Day 3	0.8	0.7	0.7	0.5	0.8	0.7	17%
The average growth rate							**76%**



Graph 1. Height of the Mung plants of three types of water with error bars of ±0.05

To test the hypothesis, an experiment was designed to compare the effects of different types of water on the rate of Mung plant growth. The results of the three day experiment yielded both qualitative and quantitative results. To begin, the qualitative results showed that the plants started to germinate on Day 1 which continued up to Day 3. Especially, in Day 3, the seed coats started to peel off, showing the cotyledons of the seeds clearly. Also, the color changes were observed where in Day 1, the color of the

seed was mostly light green, while it eventually turned into a light purple color in day 3. With the visual observations, the mung plant with tap water that is mixed with hydroponic solution was growing faster than the other two types of water like tap water and mineral water. Specifically, in Appendix A, table 4, mung seeds in the tap water mixed with hydroponic solution are the only seeds that are germinated. Moreover, even in table 8, the plants in hydroponic solution mixed with tap water seemed to have the thickest and the longest stems compared to the other two groups. For tap and mineral water, plants with mineral water seemed to grow faster than the ones grown in the tap water.

In addition to these observations, there were records made of quantitative results based on the length that the seedlings grew during the germination process. During the experiment, it was done in a place where all factors such as temperature and lighting were constant to prevent any skewed results. Initially, all types of water showed similar results of the height where the difference of the height seemed minimum. However, starting from Day 1.5, the clear difference appeared as the height of the plants became different, too. In terms of calculating the height of the plants, the data from all 5 trials were used to get the average for each type of water. In table 2~5, they all show the height of the plants for all types of water, and particularly, table 2 shows the summarized results of the experiment. Based on table 2, mung seeds in the tap water mixed with hydroponic solution have the fastest growth rate as shown by the highest height by 0.86 cm with the average growth rate of 86%. The second highest growth by 0.7 cm is shown by the mung plants in the mineral water with the average growth rate of 65%. Lastly, mung plants in the tap water had the slowest growth rate with 0.62 cm with the average growth rate of 76%. Such differences in the height of plants can also be seen in Graph 1 where all types of water with respective plant height is summarized by days. With this, even though mung seeds in tap water mixed with hydroponic solution have the fastest growth rate including highest height of the plant, all types of water also seemed to have similar growth rates as well.

Analysis

Both the qualitative and quantitative results showed that plants grown in all types of water have similar growth rates; these outcomes were supported statistically though an anova test. Anova test is utilized in this experiment since there are more than two independent groups being tested. Looking at table 6, it shows the calculated F-value, P-value, and F-critical value. With these numbers, the decision to whether reject or fail to reject the null hypothesis is determined.

Table 6. The anova test (single factor) for heights of plants in each type of water.

	ANOVA					
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.05477333333	2	0.027386666 67	0.4532215 357	0.64602311 2	3.885293835
Within Groups	0.72512	12	0.060426666 67			
Total	0.7798933333	14				

To interpret the value, when the F-value is greater than the critical value, and P-value is less than the level of significance; these mean to reject the null hypothesis or simply, H_o. However, when the F-value is less than the critical value, and the P-value is greater than the level of significance, this then means to fail to reject that H_o. Also, in this experiment, the level of significance is set to be α=0.05.

F-value < F-Critical value = fail to reject H_o

0.453 < 3.885

P-value > Level of significance = fail to reject H_o

0.646 > 0.050

In this paper, F-value is less than the critical value, and the P-value is greater than the level of significance which concludes that the null hypothesis should not be rejected; thus, the alternative hypothesis is incorrect. To simplify, this means that the mung seeds in all types of solution have similar growth rates.

This outcome is further reinforced by data in table 2 showing the results of this experiment have the standard deviation for each type of water. To interpret the standard deviation, when the value for the standard deviation is less than 1, it means that the data is not spread out from the mean, and the data is precise at the same time. However, when the standard deviation is greater than 1, then it means that the values are not close to the mean, and not precise at the same time. For example, in this experiment, the results for tap water with hydroponic solution has a standard deviation of 0.285 which stands for a low standard deviation. This means that the data is not spread out from the mean which then the data is precise, too. This then repeats for mineral water and tap water where they have standard deviation of 0.219 and 0.907 respectively. Therefore, with the standard deviation for each type of water, it is clear that the data from the experiment are close to each other, and also become precise enough to prove the significance of the data.

To reiterate, based on the result, the mung seeds in all types of water seemed to have similar growth rates as summarized in tables 3 to 5. The reason why all types of water showed similar results is that all types of water contained enough nutrients for Mung seeds to germinate and grow. For instance, the minerals in “Samdasoo” contain several healthy minerals such as irons, calcium, potassiums, magnesium, vanadium, and silica which all contribute to the growth of the Mung plants (Kim, YS., 2020). The reason why the mung seeds in mineral water also showed growth rate that was fast but not as fast as the rate for plants in tap water mixed with hydroponic solution is because some common chemicals were present in the solution such as potassium and calcium which are considered as chemical substances that bring a positive effect to plants. Also, for the tap water, it showed the lowest growth rate because it contained iron and copper which can be beneficial to plants, but with great quantities of these minerals, the plants can be exposed in toxic conditions. Thus, the tap water would not have contributed to the growth as much as the mineral water or hydroponic solution water did.

However, despite the fact that there are similar rates in all types of water, it is clear and evident that the mung plant in tap water mixed with hydroponic solution has the highest growth rate. Thus, this outcome required the researcher to consider what the 'nutrient rich hydroponic solution' provides in terms of specific chemical components to facilitate plant growth. Based on the research, it was found that Plant Partner's Type A contains various chemical components for plants' benefits. Firstly, nickel, a micronutrient that fosters extra nitrogen fixation to support plant metabolism that contributes to germination of plants ("Nickel"). Secondly, nitrogen itself is used to provide energy for plants to grow (Mas. J, 2013). Thirdly, the solution contains calcium which plays an important role in protecting the plants from disease and pests (Hassani. N, 2019). Fourthly, the ions in it are used by plants to make chlorophyll which is used in photosynthesis ("Mineral Ion Deficiencies - Plant Disease"). Fifth, a little amount of chromium in the solution is used for plants so that they can promote growth and increase the yield (Oliveira. H, 2012). Lastly, potassium is the way to strengthen plants' ability to resist disease and also increase crop yields with improvement on overall quality ("Potassium"). These chemical elements in hydroponic solution actually contribute to the growth of plants which then resulted in the fastest growth rate, too. Furthermore, tap water with hydroponic solution also contains other vital chemical substances such as amino acids and glutamic acids which boost the growth of the plants.

Conclusion

To sum things up, the experiment was conducted to see if the growth rate of mung seeds based on their measured height would differ depending on the kind of water used. Specifically, the question "To what extent do various types of water affect the growth of Mung seeds hydroponically grown?" was to be answered. While the statistical analysis indicated the null hypothesis be accepted (that the kind of water had no impact on how fast the plants grew), the results also showed how mung seeds in tap water

mixed with hydroponic solution had an overall faster rate of growth than the other plants to which other two types of water were applied.

Despite the results, some limitations were also present. For one, a primary requirement for mung seed to germinate is the presence of moisture; thus, as long as mung seeds remain soaked in water (no matter what the content), these germinate and grow. For another, setting up mung seeds without soil media, and only in water, allows these direct availability of needed water and nutrients; this may account for the little variability in their growth rates. Finally, while the variability of the water content may not be significant to the measured height, this could have affected other features of the mung plants' growth, such as contributing to a difference in color and stem thickness.

Furthermore, during the data gathering phase while measuring the length of the plants, it was possible that the length was measured differently since an old manual ruler was used. This issue can be solved by using an application for measuring or a new manual ruler with clear graduation. Also, it is possible that the temperature of the room could have varied given the cold environmental temperature outside. With the present limitations, some recommendations are suggested for future investigation on this topic. For example, future researchers can use electronic measuring tools to minimize uncertainties. Also, researchers could use a plant incubator or build a shelter for plants to control the temperature more accurately.

Appendix

Appendix 1. Qualitative data taken from the experiment

A. Qualitative Data:

Table 7. The photos of the mung seeds in different types of water on Day 1

	Day 1	
Tap water with hydroponic solution		● The seeds germinated. ● The stem of the seeds started to appear. ● The color of the seeds is dark green.
Tap water w/o hydroponic solution		● The seeds are germinated, yet the stem of the seeds are not appearing yet. ● The color of the seeds are light green.

Mineral water		• The seeds germinated. • The stem of only one seed started to appear. • The color of the seeds is dark green.

Table 8. The photos of the mung seeds in different types of water on Day 1.5

	Day 1.5	
Tap water with hydroponic solution		• The stem of the two seeds is growing. • The color of the seeds is dark green.

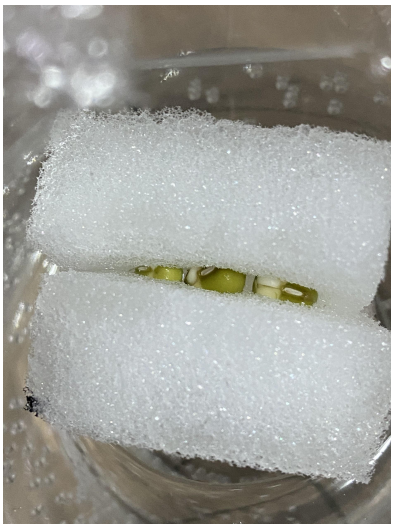
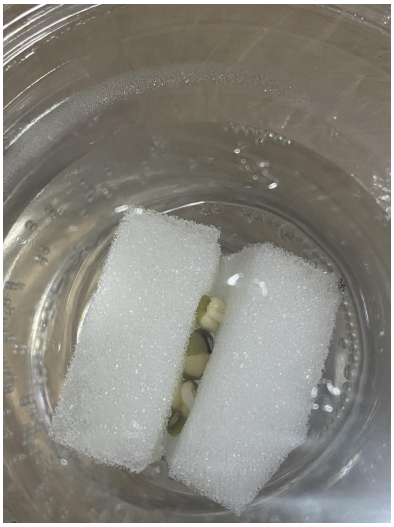
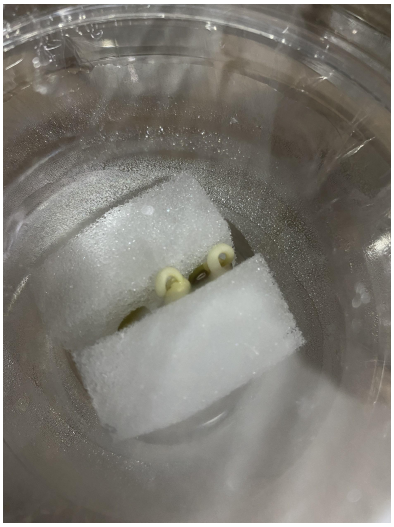
Tap water w/o hydroponic solution		• The stem of the two seeds is growing. • The color of the seeds is green
Mineral water		• The stem of two seeds is growing. • The color of the seeds is green

Table 9. The photos of the mung seeds in different types of water on Day 2

	Day 2	
Tap water with hydroponic solution		• The stems of the seed are clearly visible. • The color of the seeds is dark green.
Tap water w/o hydroponic solution		• The one seed has a clear stem while the other two seeds have shown the separation of the outer layer. • The color of the seeds is green.

Mineral water		• The one head of the stem is appearing. • The green part of the seeds is getting removed. • The color of the seed is mostly light yellow.

Table 10. The photos of the mung seeds in different types of water on Day 2.5

	Day 2.5	
Tap water with hydroponic solution		• The stems of two the seeds are already • The color is light yellow.

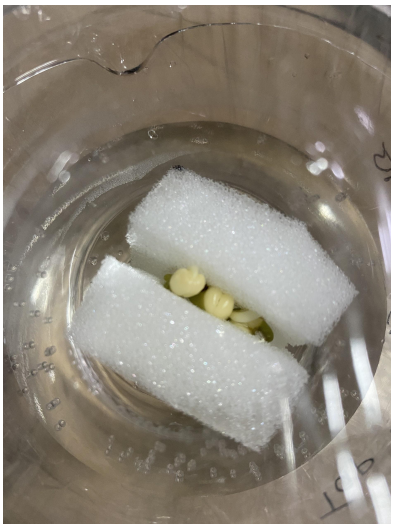
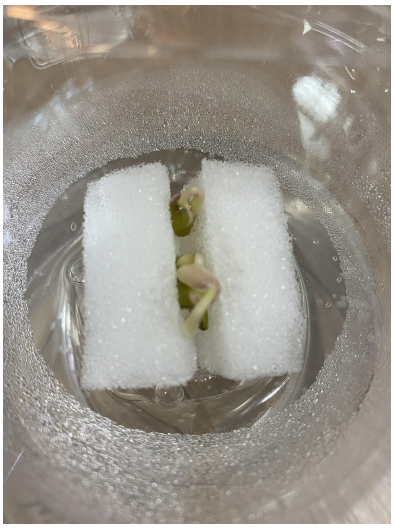
Tap water w/o hydroponic solution		• The yellow part of the seeds are appearing clearly. • Green parts of the seeds are separated from the stem and the head of the seed.
Mineral water		• The seeds still have some green parts, but most likely the seeds are light yellow.

Table 11. The photos of the mung seeds in different types of water on Day 3

	Day 3	
Tap water with hydroponic solution		● The mung plant has grown where the head is clearly shown out of the sponge. ● The color of the plant is greenish purple.
Tap water w/o hydroponic solution		● The mung plant has grown where the head is clearly shown out of the sponge. ● The color of the plant is greenish light purple.

Mineral water		• The mung plant has grown where the head is clearly shown out of the sponge. • The color of the plant is greenish light purple.

Appendix 2. Summary of observation for all samples.

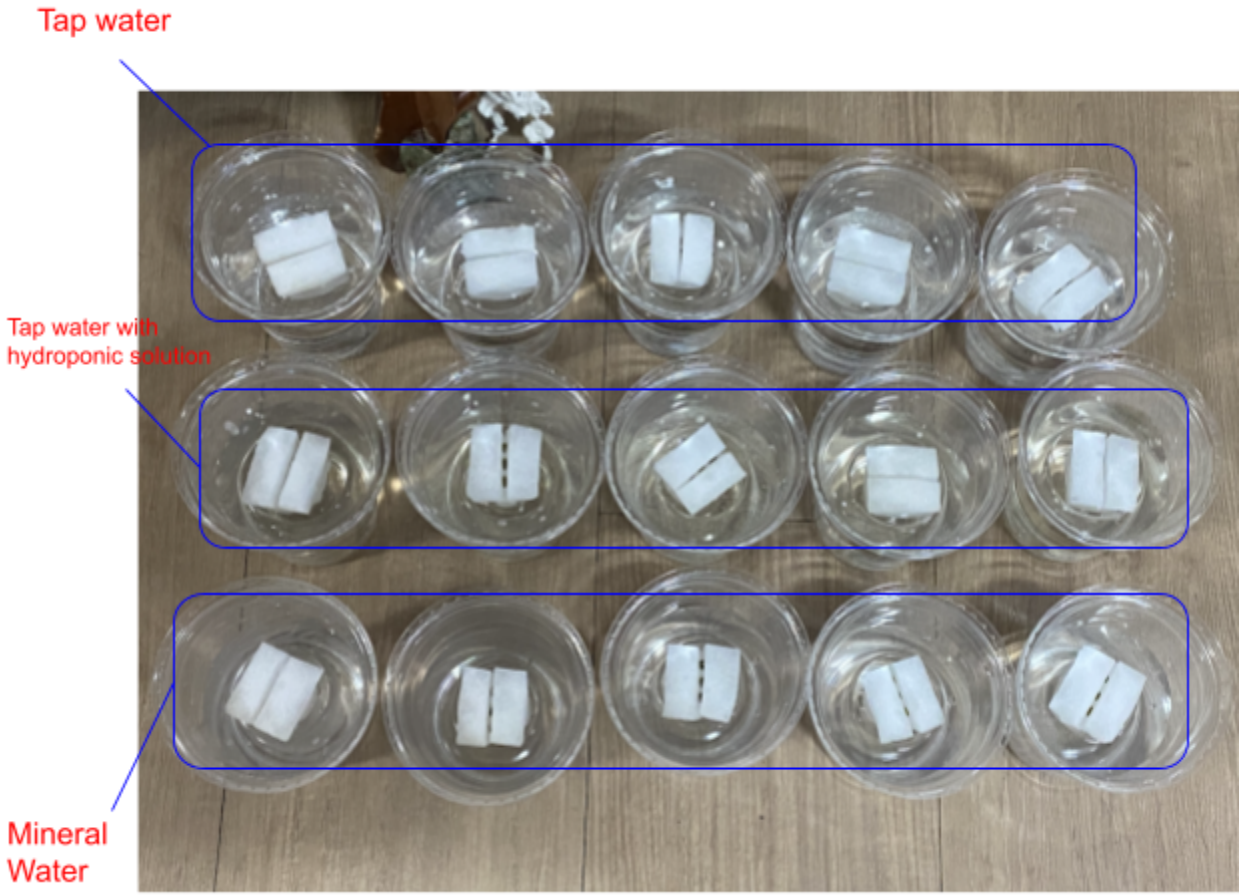


Figure 1. The overall view of the all samples with different types of solution.

Appendix 3. Calculation of the uncertainty .

Uncertainty = Minimum measurement of the tool ÷2

$$0.1\,mm \div 2 = \pm\ 0.05\,mm$$

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