The Effect of Magnets on Germination and Plant Growth of Radish and Tomato Seeds.

Research Question:

How do the magnetic fields of Y30BH ferrite magnets affect the germination and plant growth of *Raphanus sativus* and *Solanum lycopersicum* seeds?

Subject: Biology

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Table of Contents

Research Question

The research question that this experiment investigated was: How do the magnetic fields of Y30BH ferrite magnets affect the germination and plant growth of *Raphanus sativus* (radish) and *Solanum lycopersicum* (tomato) seeds?

Introduction

I wanted to explore if there were ways to increase crop yields since there is a growing food crisis in our world due to population increase. Increasing crop yields could also help countries with high rates of hunger and food insecurity. I did some research and came across an article about using magnets to enhance the growth of wheat and barley (McCormack 57). Strong horseshoe magnets were used to treat the seeds and results showed a difference between the magnetically treated seeds and the untreated seeds. This was one of the few articles I saw on this topic. Most of the studies, including the previous, are older so there is a lack of recent studies which piqued my interest as I wanted to investigate this relationship and see if it would be applicable in agriculture which led me to design this experiment.

To test the question I designed an experiment using ferrite ring magnets which had a grade of Y30BH and 5.5 kg pull, “the force required to prise a magnet from a flat steel surface” (First4Magnets, “How Is the Strength of a Magnet Measured”)). Additionally, stacked magnets (placing two magnets together) were used to measure if the intensity of the magnetic field influenced the growth of the plants. Acrylic rings were used instead of the magnets in the pots that received no magnetic field (NMF). This was done to increase fairness between the values.

The experiment was done on two species of crops; radish and tomato. The seeds were placed inside the hole of the ring-shaped magnets or acrylic pieces. Data was recorded for germination day and height of the radish and tomato seeds over 10 days. These measurements were then used to examine the relationship between magnetic fields and plant growth.

Background Information

The independent variable of the experiment was the presence of a magnetic field during the growth period. A group of seeds was exposed to a stronger magnetic field (DMF) produced by stacked magnets. Another group was exposed to a magnetic field produced by single, unstacked magnets (SMF). The last group was not exposed to a magnetic field. The magnets used in this experiment were Y30BH grade magnets. These magnets have a remanence of 3.8 - 3.9 kilogauss (kG) (First4Magnets, “Grades of Ferrite Magnets”). Remanence is “the magnetism that is left in a magnet after the removal of the external magnetic force applied to magnetise it” (First4Magnets, “How Is the Strength of a Magnet Measured”). In other words, it is the magnetic force that a magnet has by itself without any external forces. Gauss is the measurement used for remanence and it “refers to the intensity of the magnetic field” (Adams Magnetic Products) in a specific area. The gauss of a magnet is commonly measured at the poles which produce the largest amount of force. These are not the strongest magnets but they will allow for the experiment to be carried out and data to be collected.

To increase the magnetic force of the magnets, 2 magnets were placed together creating a double magnet. Stacking the magnets increases the intensity of the magnetic field. This was done to observe the effect of an increased magnetic field on the growth of the plants. This then resulted in three different values being measured; growth of seeds exposed to a DMF, SMF and NMF.

The magnetic field of the magnet depends on the way it has been magnetised. There are many different ways that a ring magnet can be magnetised. The three most common ways being: axially (*Figure 1*), radially (*Figure 2*) and diametrically (*Figure 3*). The magnets used in this experiment were axially magnetised (*Figure 4*).

Figure 1: *Magnet that was axially magnetised (Moermond)*

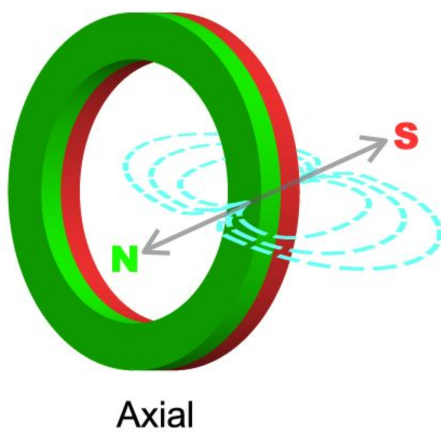


Figure 2: *Magnet that was radially magnetised (Moermond)*

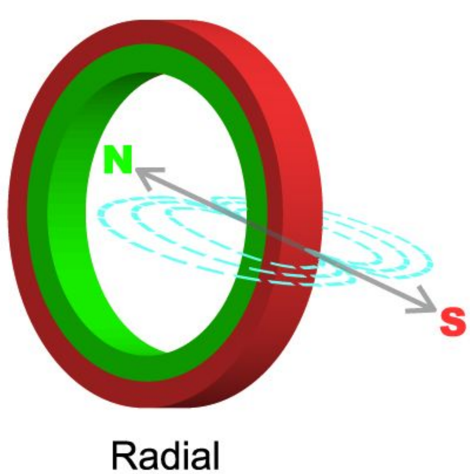


Figure 3: *Magnet that was diametrically magnetised (Dura Magnetics)*

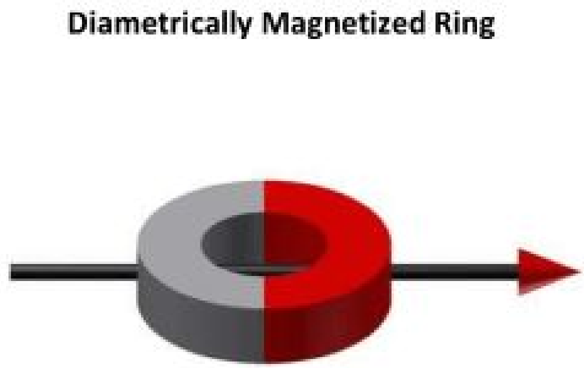
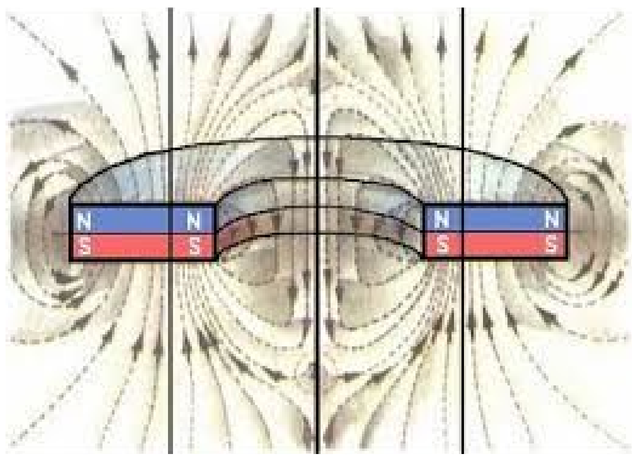


Figure 4: *Magnetic field of an axially magnetised ring magnet (Magnetic Field)*



The dependent variable of this experiment was the germination and plant growth of the radish and tomato seeds. In normal conditions, germination of seeds would be affected by light, temperature, soil type, water availability and the depth at which the seed was planted. These factors were kept constant in this experiment to ensure the effects of the magnetic field were the only factor influencing germination. Recording the day of germination pointed out this relationship and could be plotted on a graph to clearly see the variation between the intensities of the magnetic fields.

Plant growth, in normal conditions, is largely affected by temperature, light, humidity and nutrients and water availability. As with the factors associated with germination, these factors were also kept constant to guarantee that the magnetic fields were the only factor enhancing or limiting the rate of plant growth. Plant growth was measured for each seed giving sufficient data to examine the correlation between magnetic field intensity and rate of plant growth. Germination and plant growth were both measured to observe whether there was a distinction between the rates, if the rate of one was enhanced while the other was not.

Some studies have been done on the effects of magnets and magnetic fields on plant growth. One article stated that magnetic fields “can change the mitochondria in cells and enhance plant metabolism” (Grant). In the journal article by Alan McCormack, it is stated that the magnetised wheat and barley seeds “contained more moisture and more reducing sugar” (59). There were also structural changes in the mitochondria, all leading to the conclusion that magnetic fields cause an “overall intensification of cellular respiration mechanisms” (McCormack 59). However, not many recent and extensive studies have been done on this especially in relation to other crops leading me to do a small scale experiment to test for radish and tomato seeds.

Radish was chosen for its quick growth and availability. Radish is also beneficial for the body, containing many vitamins, a few being; Vitamin E, C and K, and minerals, such as; zinc, calcium, iron and phosphorus (Nandy). They also contain a “high water content” (Nandy) making them excellent for hydration. Tomatoes were also chosen for their abundance and popularity in dishes. Tomatoes provide a large amount of “antioxidant lycopene, which has been linked to many health benefits, including reduced risk of heart disease and cancer” (Bjarnadottir). Tomatoes “are also a great source of vitamin C, potassium, folate, and vitamin K”

(Bjarnadottir). Tomatoes are also grown in Norway, the country I am residing in, and are very important in the food culture of India, my birthplace. These seeds were placed in separate pots to increase the accuracy of the measurements as one species might intake more water and nutrients than the other resulting in skewed data.

Hypothesis

This led me to the hypothesis that the double magnets would enhance the germination and plant growth in the radish (*Raphanus sativus*) and the tomato (*Solanum lycopersicum*) seeds. I believed this due to the intensified magnetic field of the double magnets. Next, I believed the rate would be somewhat enhanced by the magnetic field of the single magnets. Lastly, I believed the seeds exposed to no magnetic field would have the slowest germination and growth rate.

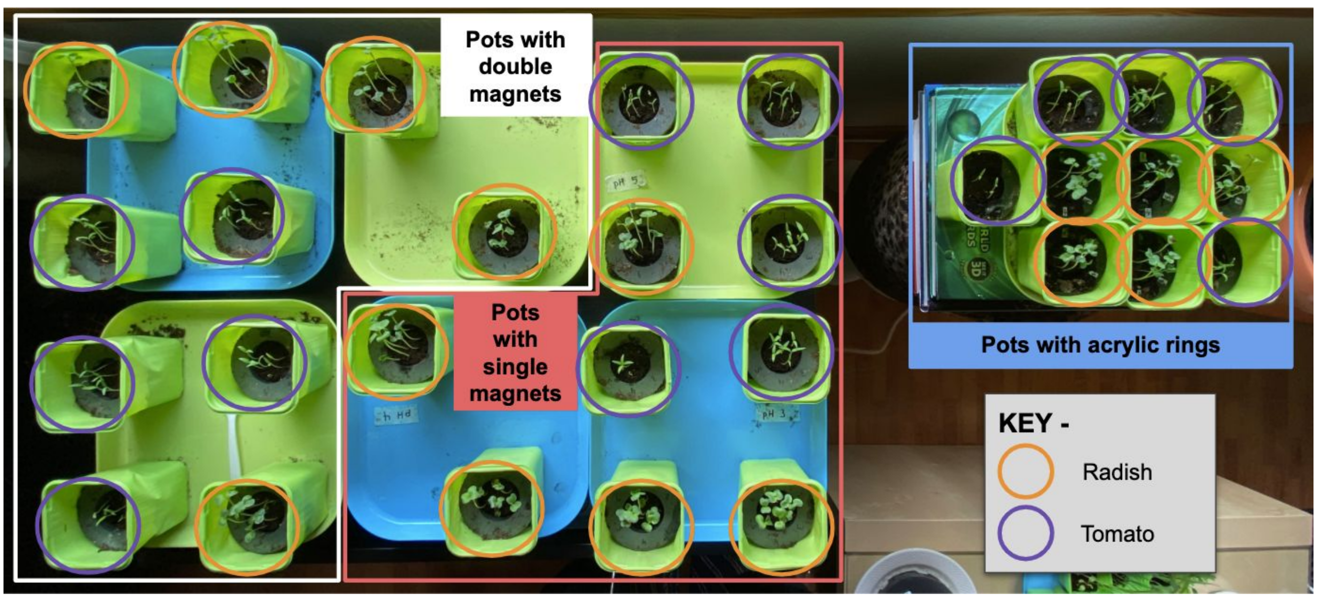
Method

As mentioned previously, the pots that contained no magnetic exposure were still placed with acrylic rings (in the same size as the magnets). This was done to increase fairness between the pots in all factors except magnetic exposure. Factors in the pots that contain magnets would be affected, such as water evaporation. The water held in the soil under the magnets would evaporate slower resulting in the seeds having it for longer giving these seeds an advantage compared to the pots without magnets. Adding acrylic rings makes all the pots equal.

Due to budget constraints, ferrite magnets with a weaker magnetic field were bought instead of stronger neodymium magnets. Neodymium magnets are significantly stronger than ferrite magnets but due to this, they are also more expensive leading to the decision of getting ferrite magnets instead.

The radish and tomato seeds were separated due to the reasons mentioned earlier. In each pot, there were seven seeds of one species. This resulted in a total of 15 pots for each species with 5 pots in each value (*Figure 5*). Having 7 seeds in each pot increased the sample size resulting in an increased reliability but also gave each seed enough space to grow.

Figure 5: *Labelled picture of pot layout with the type of magnet and the specific plant.*



The magnets repelled resulting in space between the pots. The pots without magnets were kept as far as possible from the magnetically exposed pots so they were not affected by the magnetic fields. Due to lack of space each NMF pot was closer together compared to the other pots. The positions of the pots were changed daily so each pot got the same amount of sunlight.

Variables

Independent variables:

- Magnetic exposure (DMF, SMF, NMF)
- Types of seed (radish, tomato)

Dependent variables:

- Germination (days)
- Rate of growth (height/day) ± 0.5mm

Controlled variables:

- Light exposure & intensity
- Water availability & time of watering
- Amount of soil
- Temperature
- Sowing depth
- Humidity
- Access to nutrients

Development of Method

I wanted to test whether magnetic exposure had an effect on germination and plant growth. To do this well, much testing had to take place beforehand to find the optimal conditions for the experiment.

During the preliminary experiment, I deduced that planting and growing the radish and tomato seeds directly in the soil was the best idea for the seeds. A comparison between germinating the seeds on tissue paper and directly in the soil was conducted. During this experiment, it was seen that the optimal conditions for germination were when the seed was directly planted in the soil. This was because this course resulted in the least amount of handling which was optimal for the seeds as they are very fragile. If the seeds were germinated on tissue paper, they would have to be transplanted into the pots which caused damage to the roots of the very fragile, newly germinated plants.

Magnetic exposure was also thought about. Initially, I wanted to test the difference between growth with magnets and no magnets. After testing, I was more curious in seeing whether adding a magnet would change the findings so I changed from having two values to 3 values. This also meant I had to have fewer pots though. Since 2 magnets were needed for pots that have a DMF, only 10 pots were able to be allocated for each value. I only had 40 magnets so 20 were for the DMF, and 10 were for the SMF. As mentioned above, weaker magnets were chosen due to budget constraints which also got me thinking whether double magnets would differently affect the plants compared to single magnets.

Since only 10 pots were used, I also had to test how many seeds I could plant within each pot. I needed enough seeds to yield enough data points for fair testing and analysis but not too many that the seeds are too close together. This led to having 7 seeds in each pot. 6 around the inside of the magnet and 1 in the centre of the circle. These seeds were kept track of for measuring by putting numbers on the magnets. Numbers from 1 to 6 are marked on the magnets and the 7th seed is just known as being in the middle (*Figure 6*).

Figure 6: *Picture showing the numbering system used to keep track of the seeds in each pot.*

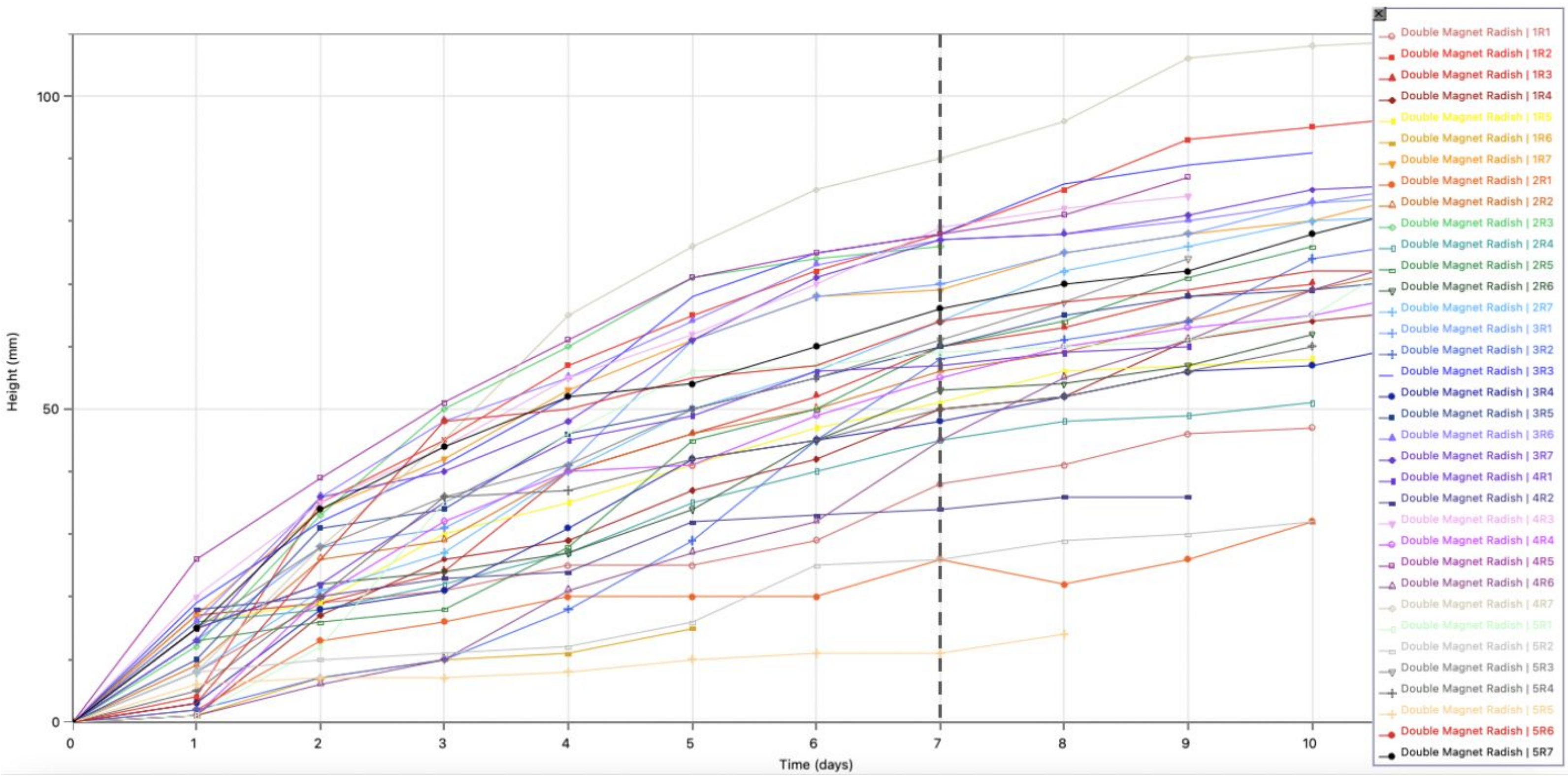
The type of seed was also considered. Radish, tomato, beetroot, carrot and lentil seeds were used during the preliminary tests. In the end, radish (*Raphanus sativus*) and tomato (*Solanum lycopersicum*) seeds were used due to the reasons mentioned above and also for their availability in stores.

All this preliminary testing resulted in my final method, having 10 pots per value with 5 of these pots having 7 radish seeds each and the other 5 with 7 tomato seeds. This resulted in 35 seeds per type (radish and tomato) for each value. For the whole experiment, there were 210 seeds.

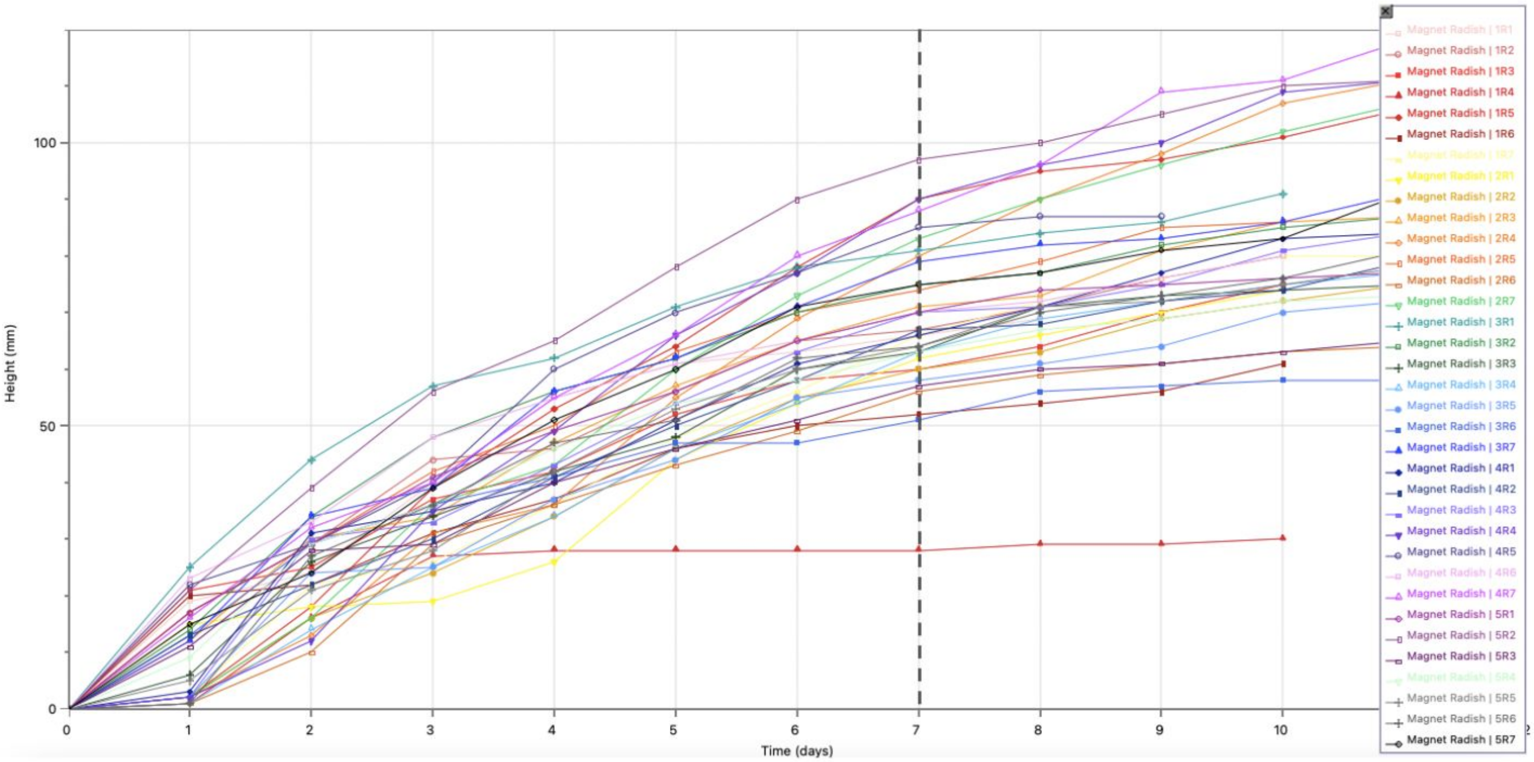
Raw Data

The following graphs were used to calculate the rates for each seed which were then plotted to create the final rate graph for the tomato and radish seeds in each degree of magnetic exposure. Raw data tables (Appendix C) were used to produce these graphs.

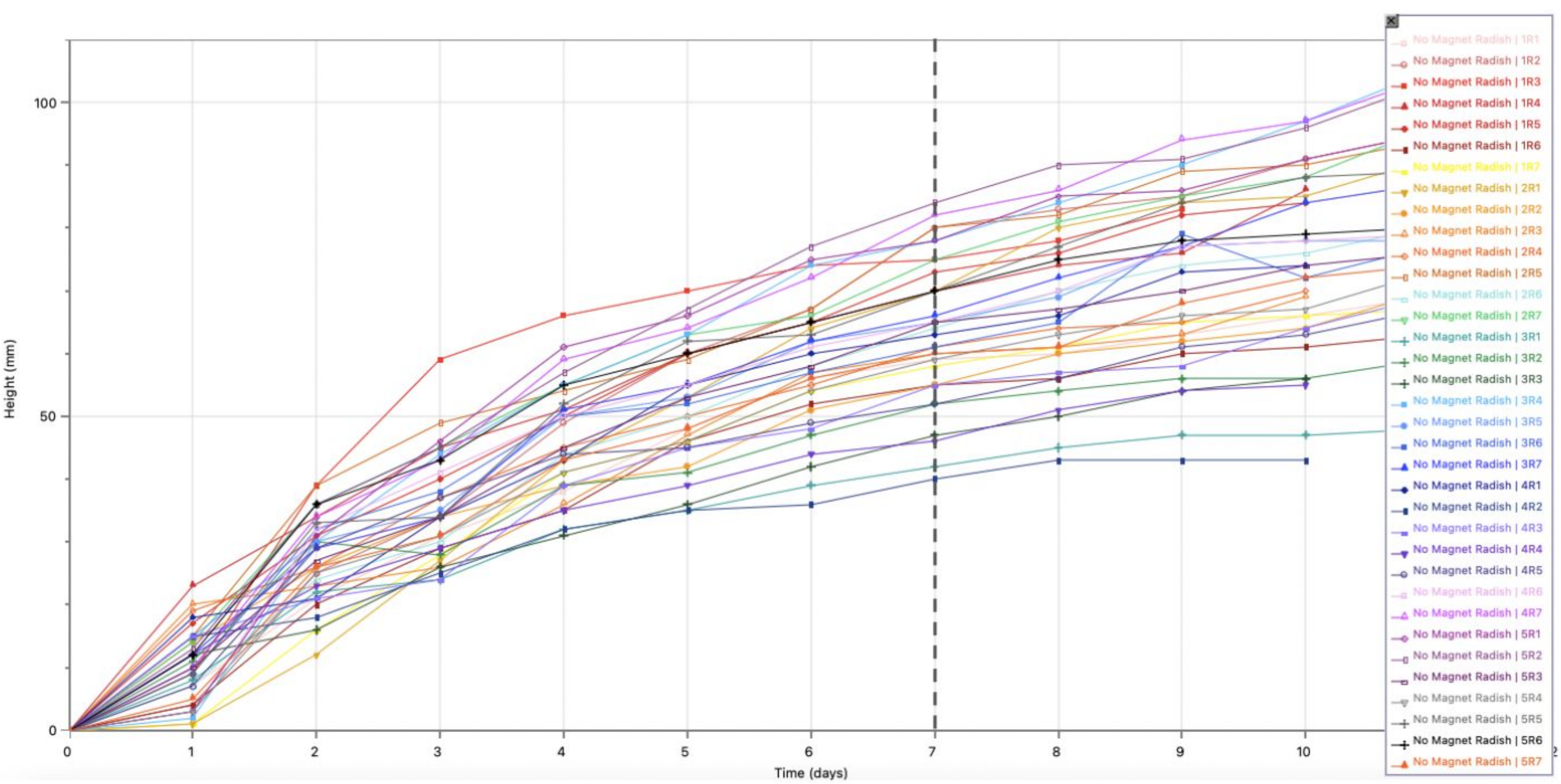
Graph 1: *Graph showing the heights of radish seeds exposed to a DMF with day 7 marked.*



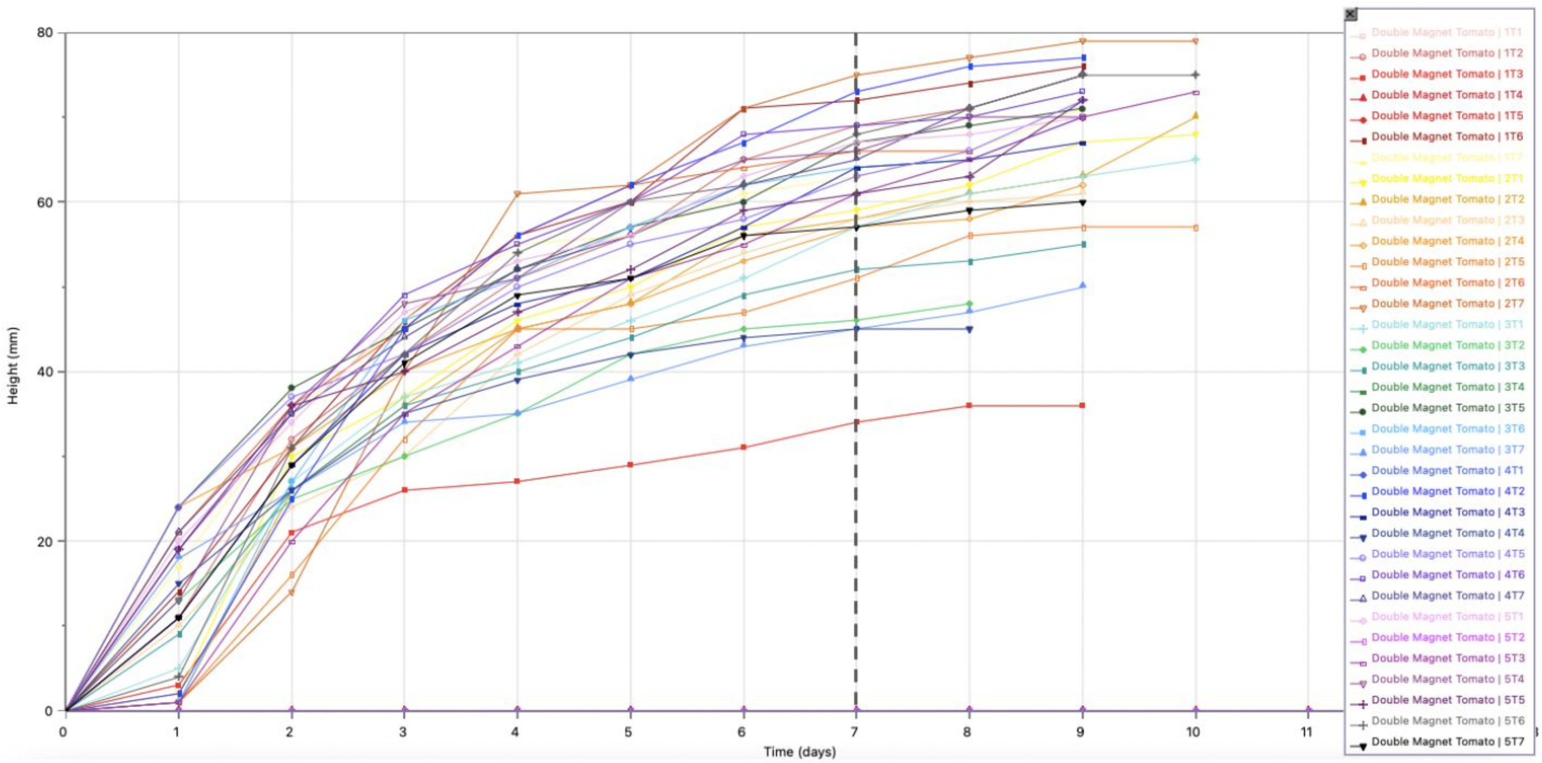
Graph 2: *Graph showing the heights of radish seeds exposed to a SMF with day 7 marked.*



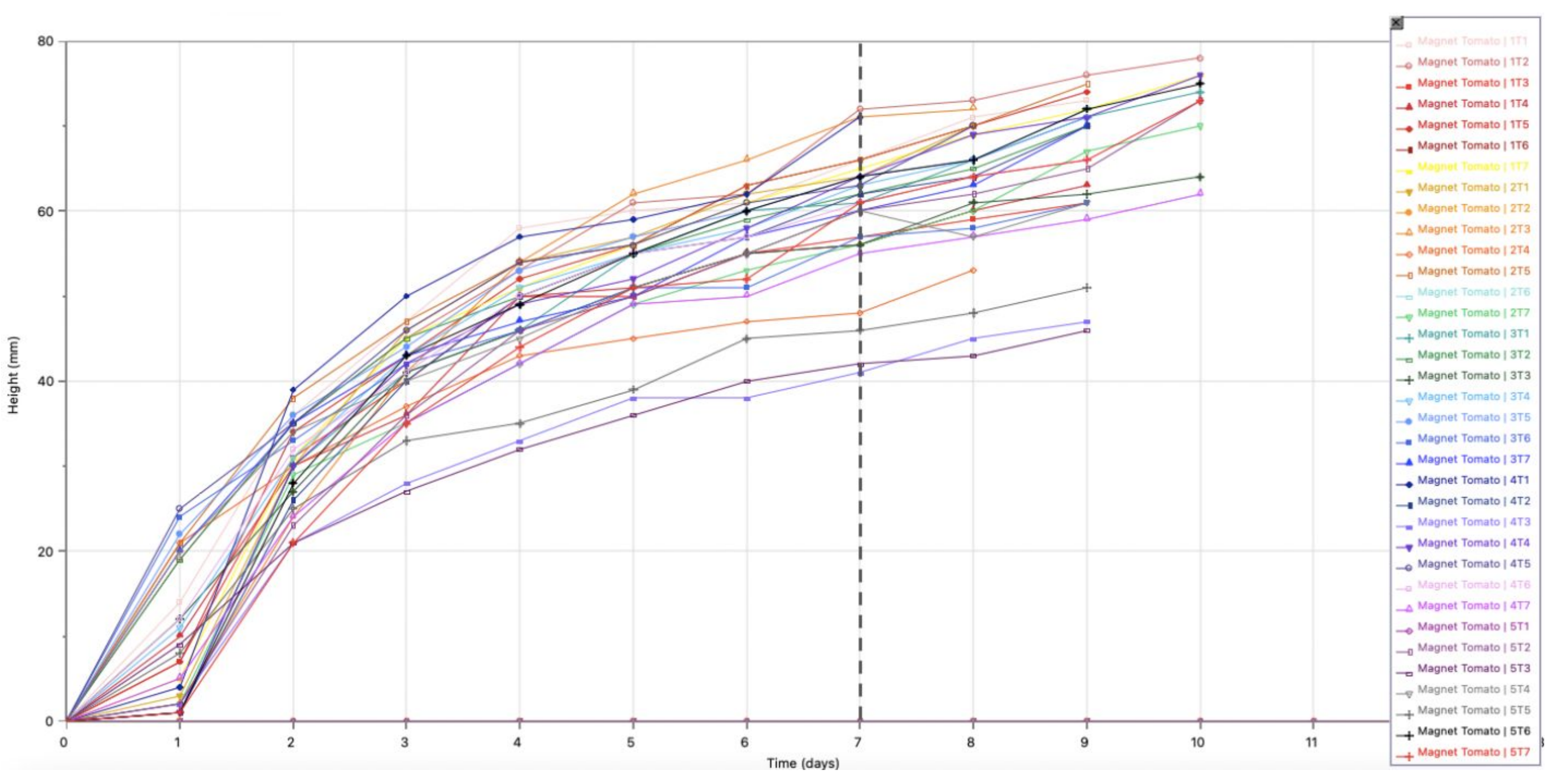
Graph 3: *Graph showing the heights of radish seeds exposed to NMF with day 7 marked.*



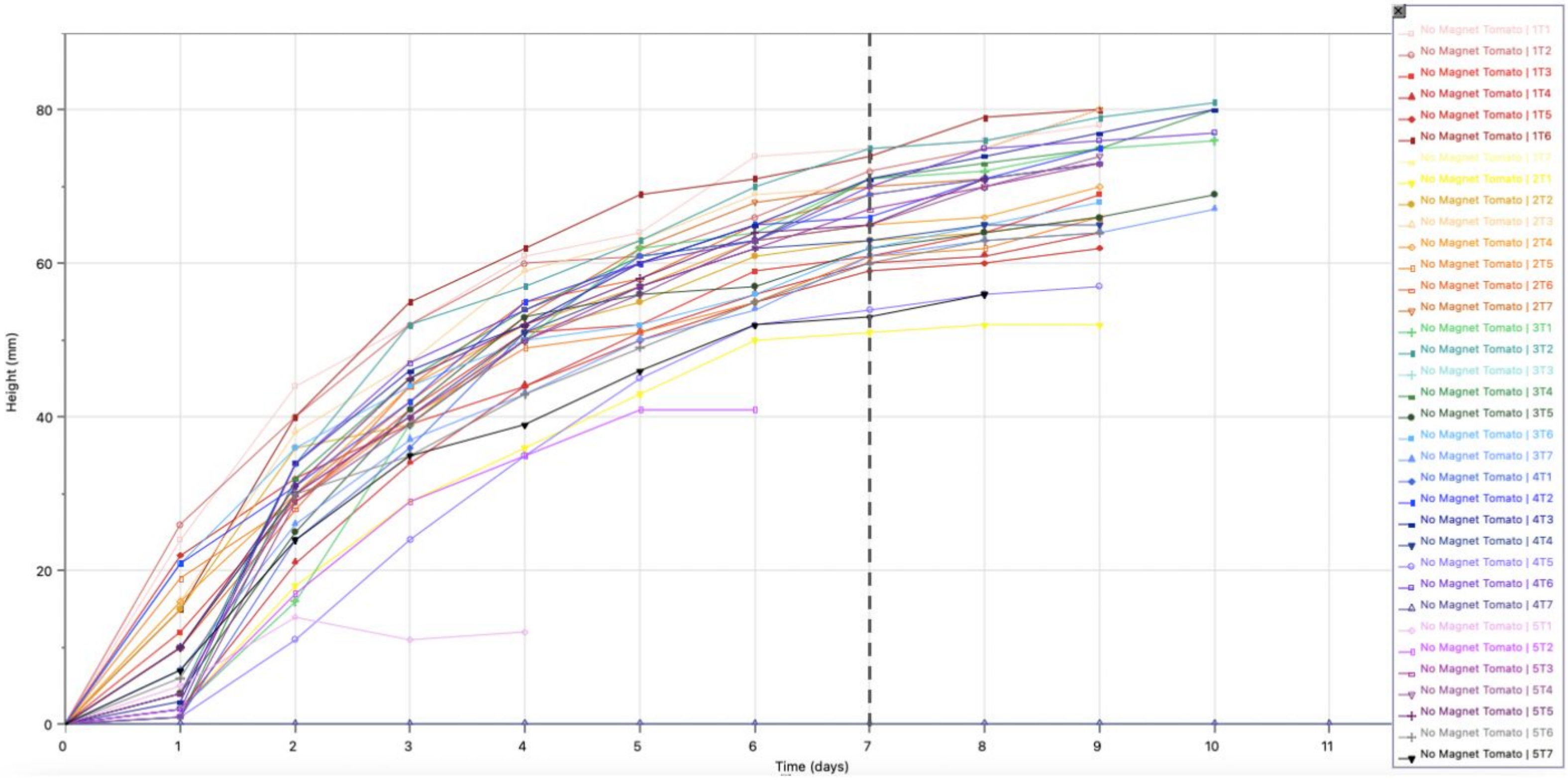
Graph 4: *Graph showing the heights of tomato seeds exposed to a DMF with day 7 marked.*



Graph 5: *Graph showing the heights of tomato seeds exposed to a SMF with day 7 marked.*



Graph 6: *Graph showing the heights of tomato seeds exposed to NMF with day 7 marked.*



It is important to note that the lines cut off because all the seeds were placed as if germination occurred on day 0. This was done to give each seed the same parameters to which the rate of growth would be measured. The rate of the seeds was only measured from day 0 to day 7. By doing this, only the optimal rate of the seeds was measured since after around day 7 the growth began to plateau and the measured rate decreased.

Processed Data & Analysis

Calculations

Calculating the Mean:

After the rates for each seed were calculated using the graphs above, the mean of the rates was found and graphed for each species and magnetic exposure.

$$Average\ Rate \pm Standard\ Deviation = \frac{The\ sum\ of\ the\ rates}{The\ number\ of\ rates}$$

The number of rates is not constant for each magnetic exposure since the amount of anomalies differed between them and not all the seed germinated.

Calculating the Standard Deviations of a Sample:

The error bars seen on the graphs below were calculated using the standard deviation. The standard deviation indicates how spread the set of data is. It produces a value that shows how the data set differs from the mean of that set. The errors bars show the standard deviation above and below the mean.

$$Standard\ Deviation = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}}$$

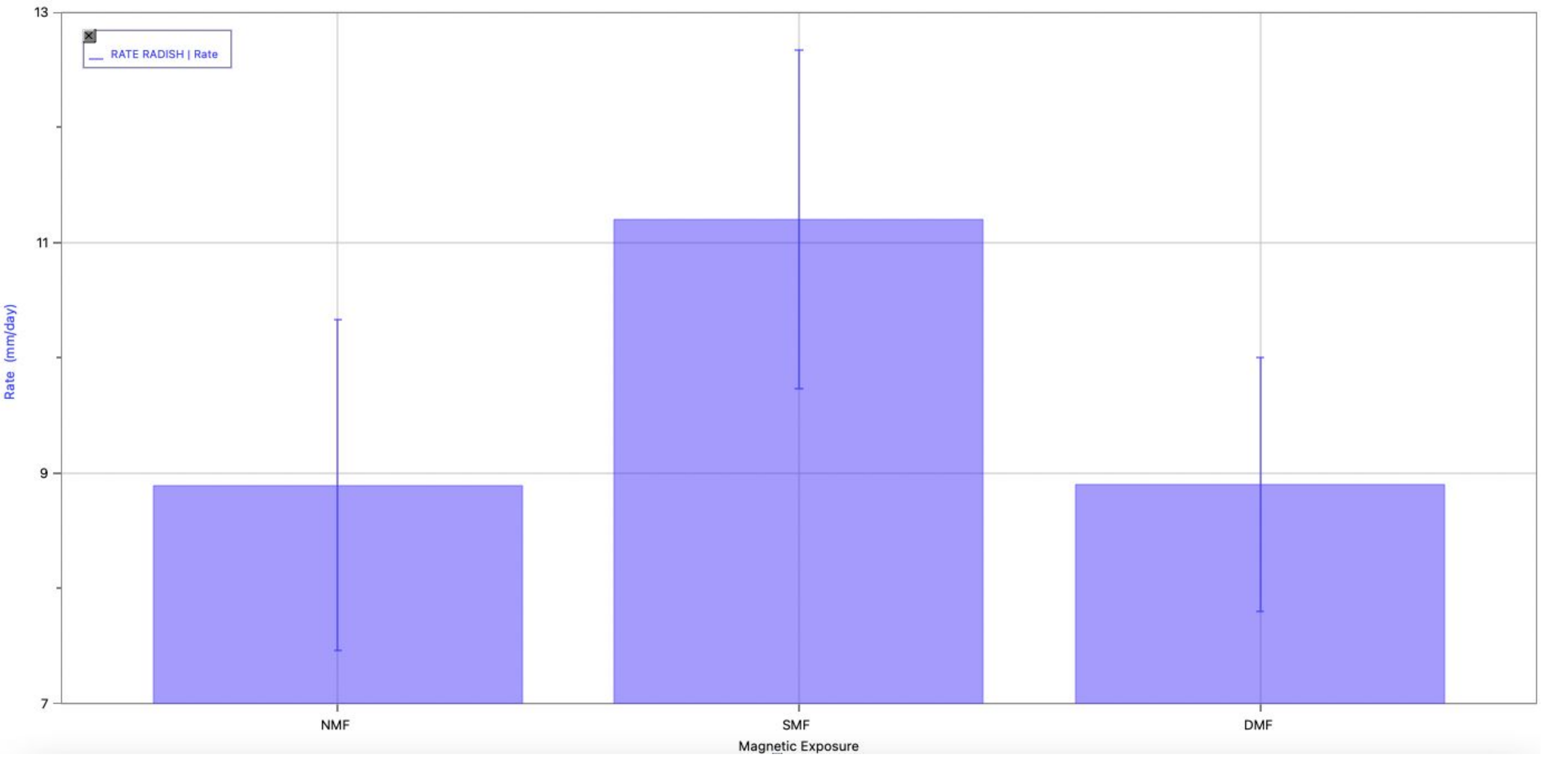
x = *each value from the data set*

$\bar{x}$ = *mean of values in the data set*

n = *number of values in the data set*

Rate of Growth

Graph 7: *Graph showing the rates for radish seeds under different magnetic exposures.*

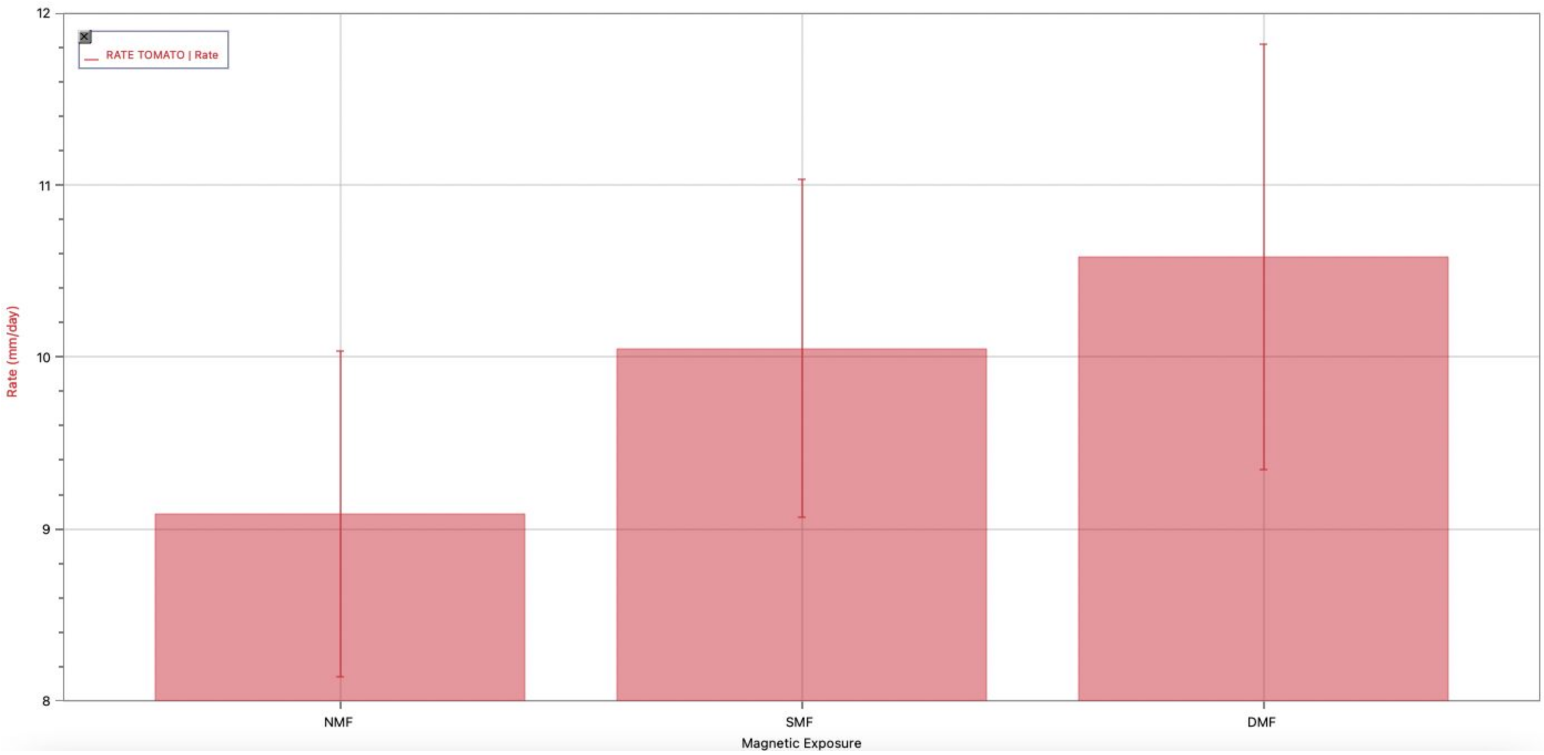


The rate of growth for the radish seedlings show a clear increased rate for the seedlings exposed to the SMF. This result was not expected, the hypothesis expected the DMF to cause the greatest growth rate although these results show that the seedlings exposed to the DMF are identical to those exposed to NMF. This could suggest that placing the magnets in this orientation in relation to the seedlings causes a different result. A higher sensitivity towards the magnetic strength is shown since a slight change in strength caused the rate to decrease from 11.2 mm/day back down to 8.9 mm/day. This is odd because research suggests that increasing the magnetic strength increases the rate of radish growth. Not many studies have been done yet the majority of them conclude that increased magnetic strength increases rate. This is explained by the increase in protein uptake as discussed previously but also increases in water uptake and other factors described below. There have also been studies done specifically on radish that see an increase in glycolipid and phospholipid content and an increase in the utilisation of polar lipids (Novitskii et al. 91).

Having the magnets horizontal and repelling each other might have changed the results of the experiment. The magnetic repulsion caused by the neighbouring magnets might have decreased the magnetic strength exposed to the seedlings. I chose to have the magnets repel due to space constraints. The space available would have resulted in the magnets connecting if put in a North-South orientation. This would have made it very difficult to rearrange the pots to ensure that all the seedlings got the same exposure to the sunlight. This orientation has a different result on the radish seedling compared to the tomato shown with their differing rate, suggesting that the radishes are more sensitive to this orientation.

Even though the SMF had a slight increase in growth rate, it becomes more significant when put in context to the overall height of the plant. These radishes are expected to grow to be 150mm tall. If they had a constant growth rate similar to that of the SMF it would take around 13 days to reach full growth. In comparison, a growth rate similar to that of NMF and the DMF would result in 17 days to reach maturity.

Graph 8: *Graph showing the rates for tomato seeds under different magnetic exposures.*

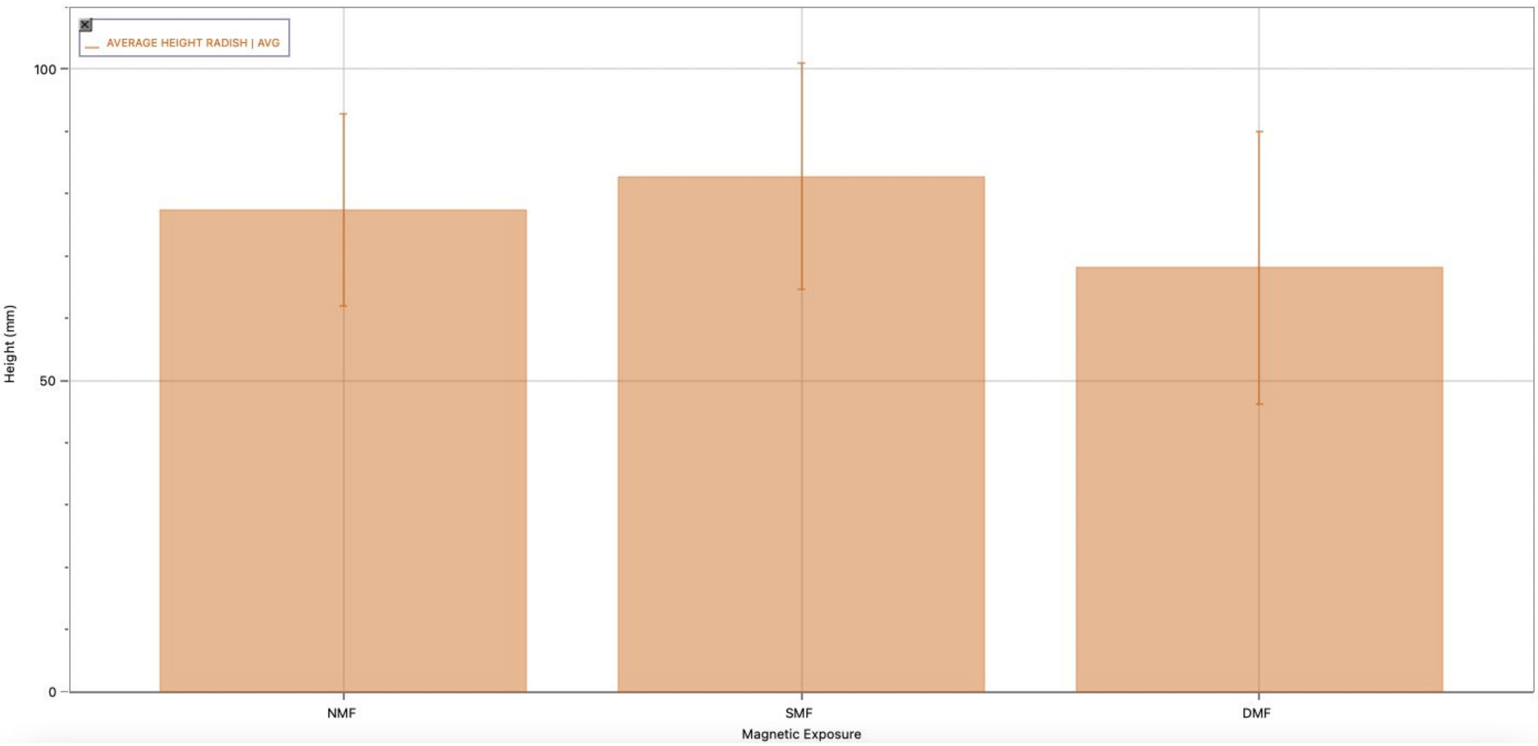


Unlike the rates of the radish seedlings, the growth rate was largest for the seedlings that were exposed to a DMF, then the SMF next and the seedlings exposed to NMF had the lowest rate having around 9.1 height/day. This suggests that magnetic exposure affects radish and tomato plants differently. This trend is in line with my hypothesis where the rate would be the highest for the DMF and lowest for NMF. This can be explained by the increase in protein synthesis done by the seedling exposed to the DMF. Research also suggests that magnetic fields increase the uptake of amino acids and increase ion movement across the plasma membrane (Stange).

Although the standard deviations do overlap, the highest rate for NMF was only the average rate for the SMF and less than the average for the DMF. When seen in comparison to the overall height of the tomato plant, a significant difference can be seen. These seedlings are expected to become 800mm tall and with the constant rate similar to the DMF (10.5 mm/day), this would occur in around 76 days. A constant rate similar to that of a NMF (9.1 mm/day), the seedlings would reach 800mm after around 88 days. This is a 12-day difference in which the plant would reach maturity which is a significant difference. Even though weaker magnets were used, a significant result was found. The results might have been more clear if stronger magnets were used which could be further looked into.

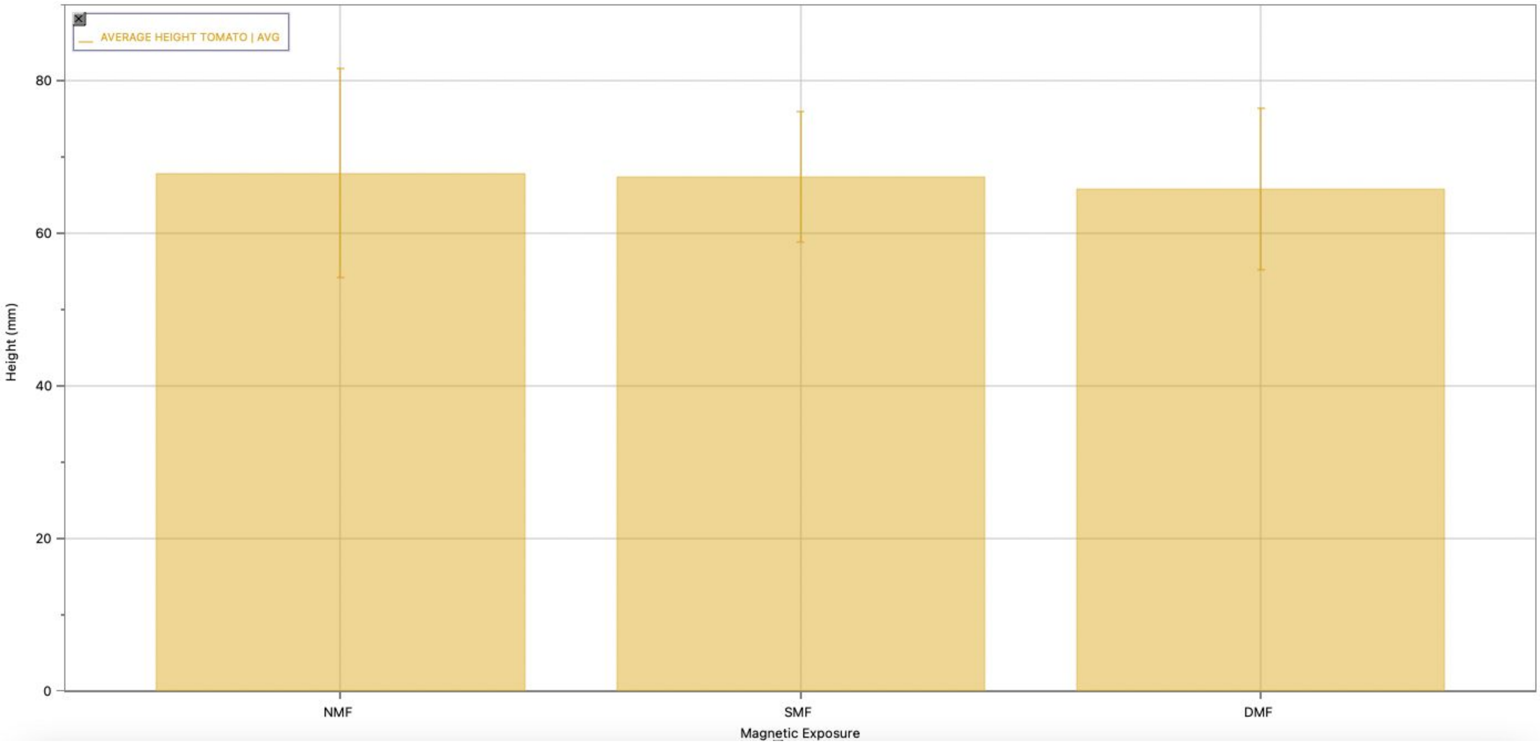
Average Final Height

Graph 9: *Graph showing the average final height for radish seeds under different magnetic exposure.*



As seen in *Graph 9*, the average final height is similar between all the magnetic exposures. This height was measured on day 13. The trend shown here subtly mirrors *Graph 7* with the SMF yielding the highest height yet not by much. Although the heights are similar, when in combination with the rate graph (*Graph 7*), it can be concluded that the seeds exposed to the SMF got to this final height the fastest as they had the fastest growth rate. The seeds exposed to the DMF or NMF took longer to get to this final height.

Graph 10: *Graph showing the average final height for tomato seeds under different magnetic exposures.*

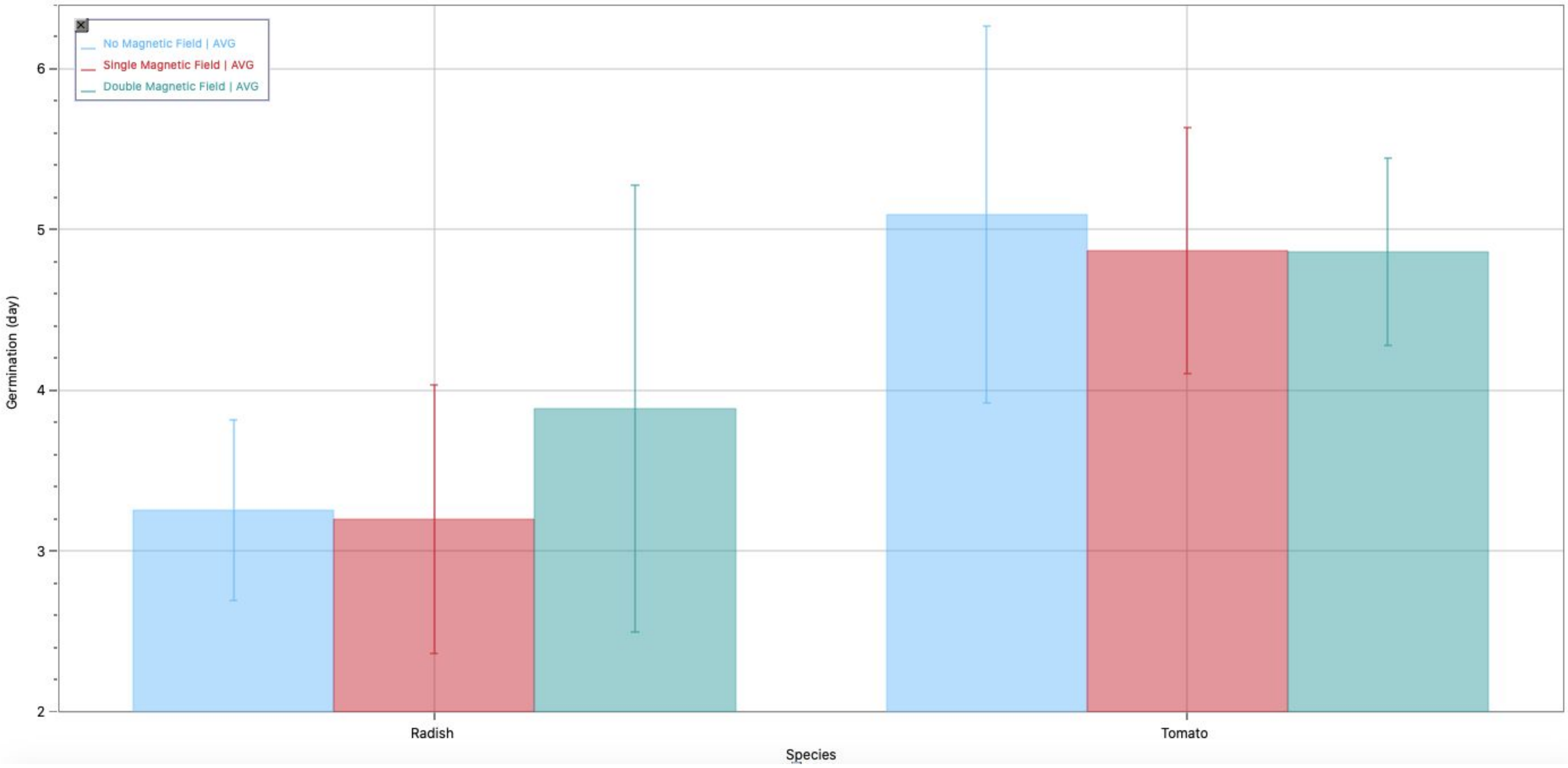


The average final height for the tomato seeds seems to be the highest for the seeds exposed to NMF yet by a very small margin. This exposure also seems to have the highest final height shown by how the standard deviation above the mean is the highest, going above 80mm. When looking at this graph with *Graph 8*, it can be said that the seeds exposed to a DMF reached this final height the quickest even though it has the lowest final height.

It seems as if the magnetic exposure does not have a significant effect on the final height of the radish or tomato seeds. It does not seem to increase the final height yet it does not have an adverse effect on the seeds either.

Average Germination Day

Graph 11: *Graph showing the average germination day for radish and tomato seeds.*



For both seeds, it can be seen that there is not a substantial difference between germination days at different magnetic strengths; all the averages show that there is never more than a day difference between the seeds. This could indicate that the magnetic exposure does not affect the seeds until germination has occurred since the rate of growth did show a difference. This is unusual since the limited research on this topic discussed the increase in protein synthesis due to a magnetic field. There are many enzymes involved in plant germination, alpha amylase, for example, that breaks down the storage of starch in the seed into simple sugars that are soluble and are used to aid in the growth of the radicle. Research also shows that magnetic fields increase water uptake of seeds during imbibition (Shine). The production of these enzymes are caused by imbibition where the seed takes up water and swells causing the seed to break open.

A reason why the magnets in this experiment did not show this trend could be because the field was not strong enough. This could be further tested with stronger magnets and possible placing the seeds in between a magnetic field (between the north and south of the magnets) for example with a horseshoe magnet.

Statistical Test

For this experiment, I decided to perform a T-test to see if there was a significant difference between the growth rates of the three magnetic strengths. The T-test was chosen instead of the ANOVA because I was less interested in seeing the difference between all three magnetic strengths and more interested in seeing the difference between the DMF/SMF and NMF. Each test had a different sample size due to differences in germination but there was always a sufficient amount to perform an independent sample T-test.

Null hypothesis: There is no significant difference in the growth rate between the 2 magnetic exposures for the radish and tomato seeds.

Alternate hypothesis: There is a significant difference in the growth rate between the 2 magnetic exposures for the radish and tomato seeds.

For this T-test, if the t-values are above the critical value (when $p = 0.05$), the null hypothesis will be rejected.

Equation used to calculate the t-values (Glen "Independent Samples"):

$$t = \frac{\mu_A - \mu_B}{\sqrt{\left[\frac{\left(\Sigma A^2 - \frac{(\Sigma A)^2}{n_A}\right) + \left(\Sigma B^2 - \frac{(\Sigma B)^2}{n_B}\right)}{n_A + n_B - 2}\right] \cdot \left[\frac{1}{n_A} + \frac{1}{n_B}\right]}}$$

$(\Sigma A)^2 = \textit{Sum of data set A, all squared}$

$(\Sigma B)^2 = \textit{Sum of data set B, all squared}$

$\mu_A = \textit{Mean of data set A}$

$\mu_B = \textit{Mean of data set B}$

$\Sigma A^2 = \textit{Sum of squares of data set A}$

$\Sigma B^2 = \textit{Sum of squares of data set B}$

$n_A = \textit{Number of items in data set A}$

$n_B = \textit{Number of items in data set B}$

Equation to find the degrees of freedom (Glen "Degrees of Freedom"):

$$\textit{Degrees of Freedom} = (n_A + n_B) - 2$$

$n_A = \textit{Number of items in data set A}$

$n_B = \textit{Number of items in data set B}$

The critical values were found using the table in Appendix D when p = 0.05 with varying degrees of freedom.

Table 1: *Table showing the t-test results.*

Magnetic Strength	T-value	Degrees of Freedom	Critical Value	Result
DMF vs. NMF (Radish)	0.0142	39	2.023	Accept Null
SMF vs. NMF (Radish)	5.5905	48	2.011	Reject Null
DMF vs. NMF (Tomato)	4.5403	42	2.018	Reject Null
SMF vs. NMF (Tomato)	3.5870	50	2.009	Reject Null

From this T-test, the null hypothesis is accepted for the DMF and NMF for the radish seeds showing no statistically significant difference which aligns with the graph as they were almost identical to each other. This suggests that at these two magnetic exposures, the production of protein within the seeds and seedlings is nearly identical. They are both effective at protein production and neither had adverse effects on the seedlings.

For the other exposures, the null hypothesis is rejected showing a statistically significant difference in the rates of the radish and tomato seedlings. For each test, the stronger magnetic exposure garnered a higher rate suggesting that the increased magnetic strength does increase protein synthesis within the seed which then enhances the growth of the plant. This is also significant since these magnets were not the strongest that could have been used and in not the ideal orientations yet they still produced a significantly higher rate as shown by these t-values.

There was not a big difference between the t-values for the DMF and the SMF for the tomato seedlings, being 4.54 and 3.59 respectively. Yet the difference is much greater for the radish seeds enough so that one rejected while the other accepted the null. This could suggest that the radish seeds are more sensitive to the increase in magnetic exposure compared to the tomato seeds since the change in magnetic strength notably decreased the rate of growth.

Conclusion

The research question I attempted to answer was: How do the magnetic fields of Y30BH ferrite magnets affect the germination and plant growth of *Raphanus sativus* (radish) and *Solanum lycopersicum* (tomato) seeds?

When looking only at my experiment, it is seen that magnetic exposure does influence the growth rate of both species. It is also seen that the growth rate differs for the radish and tomato seedlings. For both species, the seedlings exposed to NMF had the lowest growth rate and the highest rate occurred with the radish seedlings exposed to a SMF with 11.2 mm/day. On the other hand, there was little change in the germination day for both species. This was researched and stronger magnets were needed to create a more noticeable difference. I would like to test this hypothesis again when using stronger magnets.

One reason I was interested in this topic was to see if magnets could be used in agriculture and these results show a significant difference, supported by the t-test results offering an effective and simple way to increase yield. The results could be even more significant when using stronger magnets which even small companies could afford since these magnets gave results and weren't expensive. These results are very important in relation to agriculture, magnets could be used to increase yields of crops such as radish. This is a very growing issue since demographers predict that the world will have a population of 10 billion by 2050 and one of the main problems our society faces is how to feed so many people. The use of magnets could be used as a simple and effective way to help with this.

Evaluation

Evaluating the Data Collection

When collecting the data, the numbering system (*Figure 6*) I used to keep track of the seedlings worked very well allowing me to have more than 1 seed in each pot. It was very organised, easily allowing me to make a spreadsheet And accurately put my measurements there everyday

One the other hand, there were constraints, one being the space constraints causing me to keep the pots close together. I tried to counter this by keeping the pots with NMF away from the rest so they were unaffected by the magnetic field but that meant I had to keep these pots closer as seen in *Figure 5*. I also did not want the magnets to connect so they had to be repelling each other as mentioned earlier. These conditions could be improved if there was more space or I could have found another table and placed it next to the existing one to increase the space available.

Another difficulty was when taking measurements for the radish plants as they would bend towards the light and tangle with each other. The waxy cuticle is also slightly sticky which meant I had to be very careful when untangling the plants to not break them in the process. This could have been improved by connecting each plant to a toothpick, keeping it straight and providing support.

Evaluating the Online Sources

One of the main difficulties was that there were not many studies done about the relationship between magnets and plant growth and the reasons for the relationship occuring on a biological level. This made it difficult to prove reasons for why results came out the way they did. To combat this I tried to find journal articles on the subject to make sure I was taking the most accurate and reliable data. Although, due to the scarcity of research, other sources had to be used. I tried to cross reference these sources with other sources to see if they all stated the same information.

Other sources were used to find information about magnetic characteristics and aspects such as the magnetisation. Any information related to my specific magnets, the remanence for example, was taken directly from the website where the magnets were bought as they have the accurate data on the properties of the magnets.

Further Questions

After this experiment, I got very interested in how the results would change if stronger magnets were used. Neodymium magnets are stronger than ferrite magnets but also more expensive and usually come in smaller sizes so I would want to test this further but while using neodymium magnets. I am also interested to see the effect of putting a seed in between the ‘legs’ of a horseshoe magnet since then the seed would be exposed to a very strong North-South magnetic field.

Another field I got more interested in is the use of electromagnets in magnetising water. This has also been researched and put into practice in agriculture which has seen an increase in yields due to an increased water absorption in the soil and there have also been signs of aiding the desalination of water if saline water is used (Ali et al.). Other reasons for this increase in yield have been researched as well. I want to further investigate this and see if magnets can be used in this regard to help in increasing yields in agriculture.

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Appendices

Appendix A: Photo showing how the pots looked with magnets and without soil or seeds.

Appendix B: List of apparatus.

Appendix C: Raw tables of primary data which was used to make the graphs.

Appendix D: Table of critical values (MedCalc).

Appendix A

How the pots looked with magnets and without soil or seeds

Appendix B

List of apparatus used in the experiment:

- 30 permanent ferrite magnets
- 10 acrylic rings
- 30 pots (8x8x8cm)
- Soil from a local plant store
- 105 radish seeds
- 105 tomato seeds
- 30 cm ruler
- Masking tape used for labelling
- Marker used for labelling
- 6 plates to hold the pots

Appendix C

Raw data tables for the height of the radish and tomato seedlings each day for 13 days. The coloured cells show when the seed has germinated.

DMF Radish:

DAYS	DOUBLE MAGNET RADISH (POTS 1 - 5) HEIGHT (±0.5mm)																				
	POT 1							POT 2							POT 3						
	R1	R2	R3	R4	R5	R6	R7	R1	R2	R3	R4	R5	R6	R7	R1	R2	R3	R4	R5	R6	R7
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	4.0	0.0	1.0	0.0	0.0	17.0	0.0	9.0	0.0	0.0	0.0	0.0	8.0	13.0	2.0	0.0	3.0	10.0	16.0	13.0
4	8.0	35.0	17.0	17.0	16.0	0.0	34.0	2.0	26.0	0.0	16.0	13.0	15.0	21.0	28.0	7.0	19.0	18.0	31.0	36.0	36.0
5	19.0	45.0	19.0	26.0	19.0	0.0	42.0	13.0	29.0	0.0	18.0	16.0	22.0	27.0	31.0	10.0	32.0	21.0	34.0	48.0	40.0
6	21.0	57.0	24.0	29.0	30.0	0.0	53.0	16.0	40.0	0.0	22.0	18.0	24.0	40.0	41.0	18.0	41.0	31.0	46.0	55.0	48.0
7	25.0	65.0	40.0	37.0	35.0	0.0	61.0	20.0	46.0	12.0	27.0	28.0	27.0	50.0	61.0	29.0	52.0	42.0	50.0	64.0	61.0
8	25.0	72.0	46.0	42.0	41.0	0.0	68.0	20.0	50.0	33.0	35.0	45.0	34.0	56.0	68.0	45.0	68.0	45.0	55.0	73.0	71.0
9	29.0	78.0	52.0	50.0	47.0	1.0	69.0	20.0	56.0	50.0	40.0	50.0	45.0	64.0	70.0	58.0	75.0	48.0	60.0	77.0	77.0
10	38.0	85.0	60.0	52.0	51.0	7.0	75.0	21.0	59.0	60.0	45.0	60.0	53.0	72.0	75.0	61.0	78.0	52.0	65.0	78.0	78.0
11	41.0	93.0	63.0	61.0	56.0	10.0	78.0	22.0	64.0	71.0	48.0	64.0	54.0	76.0	78.0	64.0	86.0	56.0	68.0	80.0	81.0
12	46.0	95.0	68.0	64.0	57.0	11.0	80.0	26.0	69.0	74.0	49.0	71.0	57.0	80.0	83.0	74.0	89.0	57.0	69.0	83.0	85.0
13	47.0	97.0	70.0	66.0	58.0	15.0	85.0	32.0	73.0	76.0	51.0	76.0	62.0	81.0	84.0	77.0	91.0	61.0	71.0	86.0	86.0

DAYS		POT 4							POT 5						
		R1	R2	R3	R4	R5	R6	R7	R1	R2	R3	R4	R5	R6	R7
0	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
3	.0	0.0	0.0	0.0	1.0	0.0	6.0	8.0	12.0	0.0	0.0	0.0	0.0	3.0	15.0
4	.0	0.0	0.0	0.0	20.0	0.0	10.0	28.0	35.0	8.0	0.0	5.0	0.0	26.0	34.0
5	.0	15.0	18.0	20.0	32.0	26.0	21.0	45.0	46.0	10.0	15.0	20.0	0.0	48.0	44.0
6	.0	22.0	20.0	35.0	40.0	39.0	27.0	65.0	56.0	11.0	28.0	36.0	6.0	50.0	52.0
7	.0	35.0	23.0	44.0	41.0	51.0	32.0	76.0	57.0	12.0	36.0	37.0	7.0	55.0	54.0
8	.0	45.0	24.0	55.0	49.0	61.0	45.0	85.0	59.0	16.0	41.0	42.0	7.0	57.0	60.0
9	.0	49.0	32.0	62.0	55.0	71.0	55.0	90.0	60.0	25.0	50.0	45.0	8.0	64.0	66.0
10	.0	56.0	33.0	70.0	60.0	75.0	61.0	96.0	61.0	26.0	55.0	50.0	10.0	67.0	70.0
11	.0	57.0	34.0	79.0	63.0	78.0	69.0	106.0	65.0	29.0	61.0	52.0	11.0	69.0	72.0
12	.0	59.0	36.0	82.0	65.0	81.0	75.0	108.0	77.0	30.0	67.0	56.0	11.0	72.0	78.0
13	.0	60.0	36.0	84.0	69.0	87.0	83.0	109.0	77.0	32.0	74.0	60.0	14.0	72.0	83.0

DMF Tomato:

DOUBLE MAGNET TOMATO (POTS 6 - 10)

HEIGHT (±0.5mm)

DAYS	POT 1 T1	T2	T3	T4	T5	T6	T7
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	11.0	3.0	0.0	0.0	14.0	17.0
6	0.0	32.0	21.0	0.0	0.0	31.0	35.0
7	0.0	42.0	26.0	0.0	0.0	46.0	46.0
8	0.0	51.0	27.0	0.0	0.0	56.0	55.0
9	0.0	56.0	29.0	0.0	0.0	60.0	56.0
10	0.0	65.0	31.0	0.0	0.0	71.0	61.0
11	0.0	69.0	34.0	0.0	0.0	72.0	63.0
12	0.0	71.0	36.0	0.0	0.0	74.0	66.0
13	0.0	75.0	36.0	0.0	0.0	76.0	71.0

DAYS	POT 2 T1	T2	T3	T4	T5	T6	T7
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	2.0	1.0	0.0	0.0	1.0	0.0	1.0
5	30.0	26.0	10.0	24.0	16.0	0.0	14.0
6	37.0	36.0	24.0	31.0	32.0	21.0	40.0
7	46.0	45.0	30.0	40.0	45.0	36.0	61.0
8	50.0	48.0	42.0	45.0	45.0	45.0	62.0
9	57.0	56.0	49.0	48.0	47.0	56.0	71.0
10	59.0	58.0	54.0	53.0	51.0	62.0	75.0
11	62.0	61.0	58.0	57.0	56.0	64.0	77.0
12	67.0	63.0	60.0	58.0	57.0	66.0	79.0
13	68.0	70.0	61.0	62.0	57.0	66.0	79.0

DAYS	POT 3 T1	T2	T3	T4	T5	T6	T7
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	5.0	0.0	0.0	0.0	0.0	0.0	0.0
5	27.0	0.0	9.0	0.0	24.0	1.0	18.0
6	37.0	13.0	26.0	0.0	38.0	27.0	26.0
7	41.0	25.0	36.0	0.0	45.0	46.0	34.0
8	46.0	30.0	40.0	0.0	52.0	51.0	35.0
9	51.0	35.0	44.0	0.0	57.0	57.0	39.0
10	57.0	42.0	49.0	0.0	60.0	62.0	43.0
11	61.0	45.0	52.0	0.0	67.0	64.0	45.0
12	63.0	46.0	53.0	0.0	69.0	65.0	47.0
13	65.0	48.0	55.0	0.0	71.0	70.0	50.0

DAYS	POT 4 T1	T2	T3	T4	T5	T6	T7	POT 5 T1	T2	T3	T4	T5	T6	T7
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	4.0	0.0
5	0.0	2.0	11.0	0.0	24.0	19.0	21.0	20.0	0.0	20.0	13.0	19.0	31.0	11.0
6	0.0	25.0	29.0	15.0	37.0	35.0	35.0	34.0	0.0	35.0	36.0	36.0	42.0	29.0
7	0.0	45.0	42.0	26.0	42.0	49.0	44.0	47.0	0.0	43.0	48.0	40.0	54.0	41.0
8	0.0	56.0	48.0	35.0	50.0	55.0	52.0	53.0	0.0	51.0	51.0	47.0	60.0	49.0
9	0.0	62.0	51.0	39.0	55.0	60.0	56.0	56.0	0.0	55.0	60.0	52.0	62.0	51.0
10	0.0	67.0	57.0	42.0	58.0	68.0	62.0	63.0	0.0	61.0	65.0	59.0	68.0	56.0
11	0.0	73.0	64.0	44.0	63.0	69.0	65.0	67.0	0.0	65.0	66.0	61.0	71.0	57.0
12	0.0	76.0	65.0	45.0	66.0	70.0	71.0	68.0	0.0	70.0	70.0	63.0	75.0	59.0
13	0.0	77.0	67.0	45.0	72.0	73.0	75.0	70.0	0.0	73.0	70.0	72.0	75.0	60.0

SMF Radish:

MAGNET RADISH (POTS 1 - 5)

HEIGHT (±0.5mm)

DAYS	POT 1							POT 2							POT 3						
	R1	R2	R3	R4	R5	R6	R7	R1	R2	R3	R4	R5	R6	R7	R1	R2	R3	R4	R5	R6	R7
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	1.0	2.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
3	0.0	0.0	0.0	1.0	2.0	0.0	2.0	0.0	2.0	12.0	13.0	0.0	10.0	16.0	0.0	14.0	6.0	14.0	2.0	13.0	12.0
4	0.0	17.0	21.0	16.0	18.0	20.0	22.0	15.0	16.0	30.0	31.0	17.0	29.0	36.0	25.0	34.0	26.0	25.0	24.0	29.0	34.0
5	0.0	29.0	25.0	27.0	39.0	22.0	26.0	18.0	24.0	34.0	36.0	29.0	36.0	43.0	44.0	48.0	34.0	34.0	25.0	36.0	39.0
6	19.0	44.0	37.0	28.0	53.0	31.0	36.0	19.0	34.0	47.0	55.0	42.0	43.0	60.0	57.0	56.0	42.0	46.0	37.0	41.0	56.0
7	24.0	46.0	42.0	28.0	64.0	37.0	48.0	26.0	46.0	57.0	69.0	50.0	49.0	73.0	62.0	62.0	48.0	54.0	44.0	47.0	62.0
8	40.0	56.0	52.0	28.0	78.0	46.0	56.0	44.0	55.0	65.0	80.0	63.0	56.0	83.0	71.0	70.0	60.0	63.0	55.0	47.0	71.0
9	55.0	65.0	58.0	28.0	90.0	50.0	66.0	54.0	60.0	71.0	90.0	70.0	59.0	90.0	78.0	75.0	63.0	69.0	58.0	51.0	79.0
10	61.0	67.0	60.0	29.0	95.0	52.0	72.0	62.0	63.0	73.0	98.0	74.0	61.0	96.0	81.0	77.0	71.0	72.0	61.0	56.0	82.0
11	63.0	71.0	64.0	29.0	97.0	54.0	76.0	66.0	69.0	81.0	107.0	79.0	63.0	102.0	84.0	82.0	73.0	75.0	64.0	57.0	83.0
12	66.0	76.0	70.0	30.0	101.0	56.0	80.0	70.0	72.0	86.0	111.0	85.0	64.0	107.0	86.0	85.0	74.0	77.0	70.0	58.0	86.0
13	69.0	80.0	75.0	-	106.0	61.0	80.0	74.0	75.0	87.0	118.0	86.0	64.0	110.0	91.0	87.0	75.0	85.0	72.0	58.0	91.0

DAYS	POT 4							POT 5						
	R1	R2	R3	R4	R5	R6	R7	R1	R2	R3	R4	R5	R6	R7
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	3.0	13.0	2.0	12.0	0.0	0.0	16.0	17.0	21.0	11.0	9.0	5.0	1.0	15.0
4	31.0	22.0	30.0	35.0	0.0	23.0	32.0	29.0	39.0	28.0	29.0	21.0	27.0	24.0
5	35.0	30.0	33.0	49.0	22.0	33.0	40.0	41.0	56.0	29.0	36.0	28.0	36.0	39.0
6	40.0	41.0	43.0	66.0	29.0	48.0	55.0	49.0	65.0	40.0	46.0	42.0	47.0	51.0
7	51.0	50.0	54.0	77.0	40.0	55.0	66.0	56.0	78.0	46.0	54.0	53.0	51.0	60.0
8	61.0	58.0	63.0	90.0	60.0	61.0	80.0	65.0	90.0	51.0	58.0	60.0	62.0	71.0
9	66.0	67.0	70.0	96.0	70.0	65.0	88.0	70.0	97.0	57.0	63.0	64.0	64.0	75.0
10	71.0	68.0	71.0	100.0	77.0	70.0	96.0	74.0	100.0	60.0	67.0	71.0	70.0	77.0
11	77.0	72.0	75.0	109.0	85.0	72.0	109.0	75.0	105.0	61.0	69.0	72.0	73.0	81.0
12	83.0	74.0	81.0	111.0	87.0	76.0	111.0	76.0	110.0	63.0	72.0	75.0	76.0	83.0
13	84.0	79.0	84.0	115.0	87.0	80.0	118.0	77.0	111.0	65.0	73.0	78.0	81.0	91.0

SMF Tomato:

DAYS	MAGNET TOMATO (POTS 6 - 10) HEIGHT (±0.5mm) POT 1							POT 2							POT 3						
	T1	T2	T3	T4	T5	T6	T7	T1	T2	T3	T4	T5	T6	T7	T1	T2	T3	T4	T5	T6	T7
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	19.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.0	0.0	12.0	0.0	0.0	0.0	0.0
5	14.0	35.0	7.0	10.0	7.0	0.0	31.0	0.0	0.0	0.0	0.0	21.0	0.0	29.0	30.0	19.0	27.0	11.0	22.0	24.0	20.0
6	36.0	45.0	31.0	30.0	34.0	0.0	45.0	3.0	0.0	2.0	21.0	38.0	0.0	35.0	41.0	35.0	41.0	31.0	36.0	33.0	35.0
7	47.0	53.0	40.0	36.0	43.0	0.0	51.0	30.0	0.0	24.0	30.0	47.0	0.0	42.0	46.0	45.0	46.0	43.0	44.0	42.0	43.0
8	58.0	61.0	50.0	50.0	52.0	0.0	56.0	46.0	0.0	41.0	37.0	54.0	0.0	49.0	55.0	50.0	51.0	51.0	53.0	46.0	47.0
9	60.0	62.0	50.0	51.0	56.0	0.0	61.0	54.0	0.0	54.0	43.0	56.0	0.0	53.0	60.0	55.0	55.0	55.0	57.0	51.0	50.0
10	61.0	72.0	55.0	55.0	63.0	0.0	65.0	57.0	0.0	62.0	45.0	63.0	0.0	56.0	61.0	59.0	56.0	58.0	60.0	51.0	57.0
11	66.0	73.0	57.0	56.0	66.0	0.0	69.0	62.0	0.0	66.0	47.0	66.0	0.0	60.0	66.0	62.0	61.0	63.0	64.0	57.0	60.0
12	71.0	76.0	59.0	60.0	70.0	0.0	72.0	64.0	0.0	71.0	48.0	70.0	0.0	67.0	71.0	65.0	62.0	66.0	66.0	58.0	63.0
13	73.0	78.0	61.0	63.0	74.0	0.0	76.0	70.0	0.0	72.0	53.0	75.0	0.0	70.0	74.0	70.0	64.0	72.0	71.0	61.0	70.0

DAYS		POT 4							POT 5						
	T	T1	T2	T3	T4	T5	T6	T7	T1	T2	T3	T4	T5	T6	T7
0	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	.0	0.0	0.0	0.0	1.0	0.0	0.0	5.0	0.0	2.0	0.0	0.0	0.0	1.0	1.0
5	.0	0.0	1.0	2.0	30.0	0.0	12.0	24.0	0.0	23.0	9.0	20.0	8.0	28.0	21.0
6	.0	0.0	26.0	21.0	42.0	25.0	32.0	35.0	0.0	36.0	21.0	34.0	25.0	43.0	35.0
7	.0	4.0	40.0	28.0	49.0	35.0	41.0	42.0	0.0	46.0	27.0	40.0	33.0	49.0	44.0
8	.0	39.0	50.0	33.0	52.0	46.0	50.0	49.0	0.0	50.0	32.0	45.0	35.0	55.0	51.0
9	.0	50.0	55.0	38.0	58.0	54.0	55.0	50.0	0.0	55.0	36.0	51.0	39.0	60.0	52.0
10	.0	57.0	57.0	38.0	64.0	56.0	57.0	55.0	0.0	60.0	40.0	55.0	45.0	64.0	61.0
11	.0	59.0	62.0	41.0	69.0	61.0	61.0	57.0	0.0	62.0	42.0	60.0	46.0	66.0	64.0
12	.0	62.0	64.0	45.0	71.0	63.0	64.0	59.0	0.0	65.0	43.0	57.0	48.0	72.0	66.0
13	.0	71.0	70.0	47.0	76.0	70.0	66.0	62.0	0.0	73.0	46.0	61.0	51.0	75.0	73.0

NMF Radish:

	NO MAGNET RADISH (POTS 1 - 5)																				
DAYS	HEIGHT (±0.5mm)																				
	POT 1							POT 2							POT 3						
	R1	R2	R3	R4	R5	R6	R7	R1	R2	R3	R4	R5	R6	R7	R1	R2	R3	R4	R5	R6	R7
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	7.0	4.0	0.0	0.0	0.0	4.0	1.0	12.0	14.0	0.0	0.0	15.0	7.0	14.0	8.0	11.0	0.0	2.0	15.0	9.0	12.0
4	21.0	25.0	0.0	23.0	17.0	20.0	16.0	27.0	26.0	20.0	19.0	39.0	24.0	36.0	22.0	30.0	12.0	30.0	30.0	32.0	29.0
5	31.0	34.0	9.0	34.0	31.0	29.0	28.0	43.0	34.0	23.0	26.0	49.0	30.0	45.0	24.0	28.0	16.0	44.0	35.0	38.0	34.0
6	38.0	49.0	39.0	45.0	40.0	35.0	41.0	53.0	39.0	26.0	37.0	54.0	44.0	55.0	32.0	39.0	26.0	55.0	50.0	50.0	51.0
7	48.0	60.0	59.0	51.0	50.0	46.0	46.0	64.0	42.0	36.0	45.0	59.0	50.0	63.0	35.0	41.0	31.0	63.0	53.0	52.0	55.0
8	56.0	67.0	66.0	60.0	60.0	52.0	54.0	70.0	51.0	47.0	50.0	67.0	58.0	66.0	39.0	47.0	36.0	74.0	62.0	57.0	62.0
9	59.0	80.0	70.0	65.0	65.0	55.0	58.0	80.0	55.0	57.0	55.0	80.0	64.0	75.0	42.0	52.0	42.0	78.0	65.0	61.0	66.0
10	60.0	83.0	74.0	70.0	73.0	56.0	61.0	84.0	60.0	60.0	61.0	82.0	70.0	81.0	45.0	54.0	47.0	84.0	69.0	65.0	72.0
11	63.0	85.0	75.0	74.0	76.0	60.0	65.0	85.0	62.0	61.0	64.0	89.0	74.0	85.0	47.0	56.0	50.0	90.0	77.0	69.0	77.0
12	66.0	91.0	78.0	76.0	82.0	61.0	66.0	91.0	64.0	63.0	65.0	90.0	76.0	88.0	47.0	56.0	54.0	97.0	78.0	72.0	84.0
13	69.0	95.0	83.0	86.0	84.0	63.0	67.0	92.0	70.0	69.0	70.0	94.0	80.0	96.0	48.0	59.0	56.0	105.0	78.0	77.0	87.0

DAYS	POT 4							POT 5						
	R1	R2	R3	R4	R5	R6	R7	R1	R2	R3	R4	R5	R6	R7
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	15.0	0.0	7.0	3.0	10.0	3.0	13.0	10.0	3.0	9.0	12.0	5.0
4	18.0	15.0	21.0	12.0	29.0	32.0	34.0	31.0	36.0	27.0	25.0	33.0	36.0	26.0
5	21.0	18.0	24.0	23.0	37.0	41.0	43.0	46.0	45.0	34.0	31.0	34.0	43.0	31.0
6	34.0	25.0	39.0	29.0	44.0	50.0	59.0	61.0	57.0	45.0	41.0	52.0	55.0	43.0
7	43.0	32.0	45.0	35.0	45.0	55.0	64.0	66.0	67.0	53.0	46.0	62.0	60.0	48.0
8	55.0	35.0	48.0	39.0	49.0	61.0	72.0	75.0	77.0	58.0	54.0	63.0	65.0	56.0
9	60.0	36.0	55.0	44.0	52.0	65.0	82.0	78.0	84.0	65.0	59.0	70.0	70.0	60.0
10	63.0	40.0	57.0	46.0	56.0	70.0	86.0	85.0	90.0	67.0	63.0	77.0	75.0	61.0
11	66.0	43.0	58.0	51.0	61.0	77.0	94.0	86.0	91.0	70.0	66.0	84.0	78.0	68.0
12	73.0	43.0	64.0	54.0	63.0	78.0	97.0	91.0	96.0	74.0	67.0	88.0	79.0	72.0
13	74.0	43.0	69.0	55.0	67.0	79.0	104.0	95.0	103.0	76.0	73.0	89.0	80.0	74.0

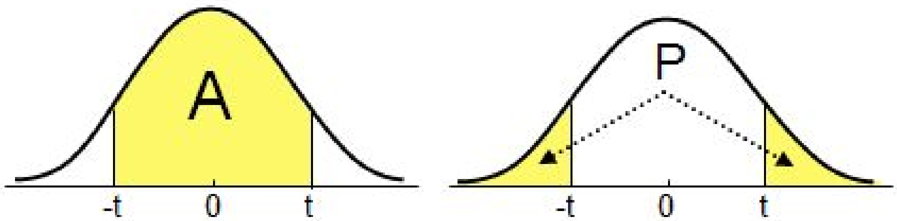
NMF Tomato:

	NO MAGNET TOMATO (POTS 6 - 10)																						
DAYS	HEIGHT (±0.5mm)																						
	POT 1							POT 2							POT 3								
	T1	T2	T3	T4	T5	T6	T7	T1	T2	T3	T4	T5	T6	T7	T1	T2	T3	T4	T5	T6	T7	T1	T2
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	4.0	0.0	1.0	4.0	0.0	7.0	0.0	0.0
5	24.0	26.0	12.0	2.0	22.0	15.0	0.0	2.0	15.0	16.0	16.0	19.0	10.0	10.0	16.0	34.0	0.0	32.0	25.0	21.0	26.0	1.0	21.0
6	44.0	40.0	29.0	21.0	32.0	40.0	0.0	18.0	36.0	38.0	30.0	29.0	28.0	30.0	39.0	52.0	0.0	45.0	41.0	36.0	37.0	24.0	31.0
7	52.0	52.0	41.0	34.0	39.0	55.0	0.0	29.0	39.0	47.0	44.0	40.0	44.0	42.0	50.0	57.0	0.0	54.0	53.0	44.0	43.0	36.0	42.0
8	61.0	60.0	51.0	44.0	44.0	62.0	0.0	36.0	51.0	59.0	52.0	49.0	55.0	53.0	62.0	63.0	0.0	61.0	56.0	50.0	50.0	51.0	55.0
9	64.0	61.0	52.0	51.0	50.0	69.0	0.0	43.0	55.0	63.0	57.0	51.0	58.0	62.0	64.0	70.0	0.0	63.0	57.0	52.0	54.0	61.0	60.0
10	74.0	66.0	59.0	56.0	55.0	71.0	0.0	50.0	61.0	69.0	63.0	55.0	65.0	68.0	71.0	75.0	0.0	71.0	62.0	56.0	61.0	63.0	65.0
11	75.0	72.0	61.0	60.0	59.0	74.0	0.0	51.0	63.0	70.0	65.0	61.0	69.0	70.0	72.0	76.0	0.0	73.0	64.0	62.0	63.0	69.0	66.0
12	76.0	75.0	64.0	61.0	60.0	79.0	0.0	52.0	64.0	75.0	66.0	62.0	71.0	71.0	75.0	79.0	0.0	75.0	66.0	65.0	64.0	71.0	71.0
13	78.0	80.0	69.0	64.0	62.0	80.0	0.0	52.0	66.0	80.0	70.0	66.0	73.0	73.0	76.0	81.0	0.0	80.0	69.0	68.0	67.0	73.0	75.0

DAYS	POT 4						POT 5						
		T3	T4	T5	T6	T7	T1	T2	T3	T4	T5	T6	T7
0	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	.0	3.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	.0	34.0	10.0	1.0	34.0	0.0	0.0	0.0	4.0	1.0	0.0	6.0	0.0
6	.0	46.0	30.0	11.0	47.0	0.0	0.0	0.0	30.0	29.0	10.0	30.0	7.0
7	.0	52.0	40.0	24.0	54.0	0.0	0.0	0.0	40.0	39.0	31.0	35.0	24.0
8	.0	60.0	51.0	35.0	60.0	0.0	0.0	2.0	50.0	50.0	45.0	43.0	35.0
9	.0	65.0	57.0	45.0	63.0	0.0	0.0	17.0	57.0	56.0	52.0	49.0	39.0
10	.0	71.0	62.0	52.0	70.0	0.0	5.0	29.0	62.0	63.0	58.0	55.0	46.0
11	.0	74.0	63.0	54.0	75.0	0.0	9.0	35.0	67.0	65.0	64.0	60.0	52.0
12	.0	77.0	65.0	56.0	76.0	0.0	11.0	41.0	70.0	70.0	65.0	63.0	53.0
13	.0	80.0	65.0	57.0	77.0	0.0	12.0	41.0	73.0	74.0	71.0	64.0	56.0

Appendix D

Section of the table of critical values (MedCalc) used to find the critical values I needed to perform the T-test. The p-value (P) was 0.05.



DF	A P	0.80 0.20	0.90 0.10	0.95 0.05	0.98 0.02	0.99 0.01	0.995 0.005	0.998 0.002	0.999 0.001
35		1.306	1.690	2.030	2.438	2.724	2.996	3.340	3.591
36		1.306	1.688	2.028	2.434	2.719	2.991	3.333	3.582
37		1.305	1.687	2.026	2.431	2.715	2.985	3.326	3.574
38		1.304	1.686	2.024	2.429	2.712	2.980	3.319	3.566
39		1.304	1.685	2.023	2.426	2.708	2.976	3.313	3.558
40		1.303	1.684	2.021	2.423	2.704	2.971	3.307	3.551
42		1.302	1.682	2.018	2.418	2.698	2.963	3.296	3.538
44		1.301	1.680	2.015	2.414	2.692	2.956	3.286	3.526
46		1.300	1.679	2.013	2.410	2.687	2.949	3.277	3.515
48		1.299	1.677	2.011	2.407	2.682	2.943	3.269	3.505
50		1.299	1.676	2.009	2.403	2.678	2.937	3.261	3.496
60		1.296	1.671	2.000	2.390	2.660	2.915	3.232	3.460
70		1.294	1.667	1.994	2.381	2.648	2.899	3.211	3.435
80		1.292	1.664	1.990	2.374	2.639	2.887	3.195	3.416
90		1.291	1.662	1.987	2.369	2.632	2.878	3.183	3.402
100		1.290	1.660	1.984	2.364	2.626	2.871	3.174	3.391
120		1.289	1.658	1.980	2.358	2.617	2.860	3.160	3.373
150		1.287	1.655	1.976	2.351	2.609	2.849	3.145	3.357
200		1.286	1.652	1.972	2.345	2.601	2.839	3.131	3.340
300		1.284	1.650	1.968	2.339	2.592	2.828	3.118	3.323
500		1.283	1.648	1.965	2.334	2.586	2.820	3.107	3.310
∞		1.282	1.645	1.960	2.326	2.576	2.807	3.090	3.291