Topic:

Effect of varying magnetic field strengths on the rate of seed germination

**Personal Engagement:**

As a nature loving person, I have always taken clean interest to participate in our kitchen garden activities. One essential pulse plant which we grow in our kitchen is mung seed. The botanical name of mung seed is *Vigna radiata. Vigna radiata* are an excellent pulse species belonging to the Legume family to study for their complex process of germination within different factors. *Vigna radiata* are highly used in the food industry, as they are high in protein, some important vitamins and other essential nutrients; these nutrients include some essential elements like calcium, and phosphorus. *Vigna radiata* amino acids provide a rich source of plant based protein diet. Furthermore, because *Vigna radiata* are used in bulk in the food industry, excellent germination becomes essential to meet high demands. In addition, the high protein content possessed by mung seeds are easy to digest. Furthermore, one more reason for mung seeds to be of interesting material for scientific explorations is because they are known to reduce risks of disease. In addition, Mung beans contain many antioxidants eg; caffeic acid, falvonoids, phenolic acids, cinnamic acid and more”[[1]](#footnote-1). Antioxidants, in general, help to neutralize harmful molecules known as “free radicals.” As a matter of fact, multiple research studies have shown that mung seeds can neutralize highly reactive free radicals related to cancer growth. These biological properties enhanced my interest to further study about mung seeds. Mung seeds are not only highly beneficial in terms of health, they also germinate rapidly under the conditions that we chose (that will be mentioned). Thus, providing for an accurate and convenient experiment to test germination of seeds.

The earth magnetic field is a natural component of our environment. Some plants known to sense different wavelengths of radiations, respond to gravity, react to touch and electrical signaling. Therefore, some plants cannot escape the effect of earth's magnetic field. While plant responses such as phototropism (response to radiations), gravitropism(response to earth's gravity), and thigmotropism (response to touch) have been thoroughly studied, the impact of earth's magnetic field on plant growth and seed germination is not intensively studied. This motivated me to explore the effect of varying magnetic strength on the mung seed germination and growth.

**Introduction & Background Information:**

The earth own magnetic field is known as geomagnetic field (GMF) and is an essential ecological factor for seed germination and plants growth. The earth's magnetic field strength varies from 25 μT (microtesla) to 60 μT [[2]](#footnote-2)(Maus et al. 2010). Although, all plant life grows and develops under the influence of this varying geomagnetic field but this abiotic factor constitutes a type of natural stress for plants and their growth[[3]](#footnote-3).

During the evolutionary line, all living organisms have experienced the action of the Earth's MF (geomagnetism) which is a natural element of their ecosystem. As the influence of GMF is continuous on plants; studies have shown it affects many physiological processes of the plants. This continuous influence of GMF on plants alters their general metabolism; which results in the increased rate of their seed germination[[4]](#footnote-4). Researchers have found a positive influence of increase in magnetic field strengths on the rate of seed germination, growth, and development of plants.

Germination refers to the physiological process by which an plant grows from a seed or a spore. The primary forms of germination process involves a seed sprouting to form a seedling and the formation of a sporeling from a spore. Therefore, germination process occurs mainly in plant and different fungal species. The process is affected by many biotic and abiotic factors of the plant ecosystem, which includes water, environmental temperature, soil types, pH of the soil in which the seed is germination. In addition, electric and magnetic fields too affect the rate of germination as they act as a stimulant for various metabolic processes occurring inside a germinating seed.

Germination of *Vigna radiata* seeds is known to be influenced by magnetic and electric fields of earth, even without applying any electric and or magnetic field. Therefore, the electric and magnetic fields are used as a stimulant to maximise the yields of crops and to promote plant growth and protect crops from different disease causing agents. The primary advantage of using magnetic field stimulation method for optimization of crop yield over traditional chemical method is the absence of toxic residues[[5]](#footnote-5). Harmful side effects of chemical exposure to crops like biomagnification or bioaccumulation could be easily avoid by using magnetic field as a stimulant for maximum crop production.

Root to shoot ratio is the ratio of the number of plant tissues that have supporting functions to the number of tissues that have growth functions. Plants with a larger ratio of roots can compete more effectively for soil nutrients, while plants with a higher proportion of shoots can gather more light energy. In our research, we’ll see how By exposing the seeds to magnets, the salt ions in the water and soil change and dissolve, creating purer water that is more easily taken up by the seed. The magnetic force pulls apart ions and changes the chemical composition of such things as salt. It also appears that magnetism and plant growth are tied together by biological impulse.

There are major spatial variations in the intensity and position of the magnetic (geomagnetic) field of the earth. In my research, I will be exploring the effect of different varying magnetic field strengths on the germination of *Vigna radiata* seeds and their root to shoot ratio.

**Aim:**

To determine whether increase in magnetic field strengths affect the rate of mung seed germination process and increase the root to shoot ratio. The mung seeds are exposed to 5 different magnetic fieldstrengths of 0, 100, 200, 300 and 500 gauss. Equal number of mung seeds placed in 5 large flower pots with same type of soil were observed for 5 days.

**Research Question:**

*To what extent do magnetic field strengths of 0, 100, 200, 300 and 500 gauss affect the seed germination and* increase the root to shoot ratio *of Vigna radiata seeds****.***

**Hypothesis: H1 (research hypothesis):**

My hypothesis is that the rate of germination of Vigna radiata seeds will increase with increase in the magnetic flied strength. Also there will be a higher number of seeds germinated in the pots with the higher strength magnets and we will be able to see more shoot growth in the pots with the higher strength magnets compared to the seeds in the pots with the lower strength magnets.

**H0 (null hypothesis):**

My null hypothesis is that the color of light will not affect the germination of the Vigna radiata seeds.

**Variables**

* *Independent Variable:* Varying magnetic field strengths of 0, 100, 200, 300 and 500 gauss
* *Dependent Variable:*
1. Number of seeds germinated
2. Root to shoot ratio.
* *Controlled variables: Table of controlled variables are listed below.*

|  |  |  |  |
| --- | --- | --- | --- |
| S.No. | *Variable* | *Reason for controlling*  | *Method of controlling* |
| 1 | Temperature  | Environmental temperature conditions affect the rate of germination. | All the seeds were germinated at room temperature.  |
| 2 | Water content of soil  | The amount of water or moisture level in the soil of germinating seeds can affect the rate of germination.  | All 5 flower parts were added with 250ml of water for every 24 hours.  |
| 3 | Age of seeds.  | The difference age of seeds could cause inaccuracies of the results.  | All mung seeds were 1 year old and were taken from single crop field.  |
| 4 | Type of soil | The type of seeds can cause variations in the rate of germination of seeds. This is due to the variation of the nutrient content required for seed germination and plant growth.  | The used in all 5 plant parts was collected from the same place.  |
| 5 | Number of seeds put in the pot | The free space available to a germinating seed can affect its rate of germination.  | All seeds were placed equidistant from each other. This ensures equal availability of nutrients and moisture for germinating seeds |
| 6 | pH level of water | Variation in pH of soil of germinating seeds can cause difference in rate of germination and plant growth.  | All the soil was collected from the same place of our garden.  |
| 7 | Light intensity | Any difference in light intensity and light exposure will cause variation in the rate of germination of mung seeds.  | The germinating mung seeds in all 5 different were exposed to sunlight for exact same duration. |

**EQUIPMENT:**

* Graduated measuring cylinder
* Graduated beaker with maximum capacity 500ml(x5)
* Gauss Meter
* 4 magnets of different strengths (100,200,300,400)
* 5 large flower pots
* Soil
* Seeds of vigna radiata plant

**SAFETY MEASURES, ETHICAL AND ENVIRONMENTAL CONSIDERATIONS**

Looking at the nature of the exploration, no major or substantial safety measures and environmental or ethical considerations are specially required. One minor thing to note is that all data should be used ethically and in accordance with the guidelines set by the database sources. These include, among other things, abiding to copyright procedures and the commercial use of the data provided.

**METHODOLOGY:**

1. Fill up the 5 large flower pots with the soil
2. Measure the size of the seeds.
3. Spread the seeds evenly
4. Place the magnets inside the soil and in between the seeds.
5. Place them in a setting w direct sunlight and controlled room temperature
6. Water the plants every 24 hours with 250ml of water.
7. Record the observations over the course of 5 days.

**RAW DATA:**

|  |  |  |  |
| --- | --- | --- | --- |
| **FLOWER POT** | **MAGNET STRENGTH** |  **FINAL NUMBER OF SEEDS GERMINATED** | **FINAL LENGTH OF THE SHOOT** |
| A | 0 | 4 | 0.5cm  |
| B | 100 | 7 | 1.9cm |
| C | 200 | 13 | 2.7cm |
| D | 300 | 18 | 3.2 cm |
| E | 400 | 22 | 4.4cm |

**CONTROL.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| POT | MAGNET STRENGTH  | 0 | Trial 1 | Trial 2  | Trial 3  | Trial 4  | Trial 5  |
| A |  |  | initial | final | initial | final | Initial | final | initial | final | initial | final |
|  | Shoot length  |  | 0cm | 0cm | 0cm | 0.02cm | 0cm | 0.2cm | 0cm | 0.3cm | 0cm | 0.5cm |
| Difference between initial length and final length |  | 0.0cm | 0.02cm | 0.2cm | 0.3cm | 0.5cm |
| MEAN |  | 0.24 | STD DEVIATION | 0.21 |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| POT | MAGNET STRENGTH  | 100 GAUSS | Trial 1 | Trial 2  | Trial 3  | Trial 4  | Trial 5  |
| B |  |  | initial | final | initial | final | initial | final | initial | final | initial | Final |
|  | Shoot length  |  | 0cm | 0.2 | 0cm | 1cm | 0cm | 0.9cm | 0cm | 1.7cm | 0cm | 1.9cm |
| Difference between initial and final length |  | 0.2 cm | 1 cm | 0.9 cm | 1.7 cm | 1.9 cm |
| MEAN |  | 1.14 cm | STD DEVIATION | 0.68 cm |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| POT | MAGNET STRENGTH  | 200 gauss | Trial 1 | Trial 2  | Trial 3  | Trial 4  | Trial 5  |
| C |  |  | initial | final | initial | final | initial | final | initial | final | initial | final |
|  | Shoot length  |  | 0cm | 1.2CM | 0cm | 1.9cm | 0cm | 2.3cm | 0cm | 2.5cm | 0cm | 2.7cm |
| Difference between initial and final length |  | 1.2 cm | 1.9 cm | 2.3 cm | 2.5 cm | 2.7 cm |
| MEAN |  | 2.12 cm  | STD DEVIATION | 0.59 cm |

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
| POT | MAGNET STRENGTH  | 300 Gauss | Trial 1 | Trial 2  | Trial 3  | Trial 4  | Trial 5  |
| D |  |  | initial | final | initial | final | initial | final | initial | Final | initial | final |
|  | Shoot length  |  | 0cm | 1.9cm | 0cm | 2.1cm | 0cm | 2.2cm | 0cm | 2.9cm | 0cm | 3.2cm |
| Difference between initial and final length |  | 1.9 cm  | 2.1 cm  | 2.2 cm  | 2.9 cm  | 3.2 cm |
| MEAN |  | 2.46 cm  | STD DEVIATION | 0.56 cm  |

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
| POT | MAGNET STRENGTH  | 400Guass | Trial 1 | Trial 2  | Trial 3  | Trial 4  | Trial 5  |
| E |  |  | initial | final | initial | final | initial | final | initial | Final | initial | final |
|  | Shoot length  |  | 0cm | 2.7cm | 0cm | 2.9cm | 0cm | 3.1.cm | 0cm | 3.5cm | 0cm | 4.4 cm  |
| Progression of the length  |  | 2.7 cm | 2.9 cm | 3.1 cm | 3.5 cm | 4.4 cm |
| MEAN |  | 3.32 cm | STD DEVIATION | 0.67 cm |

In the above analysis we can indicate the higher the standard deviation, that means that the plant faced a bigger change in its length. Hence from the general trend we can infer that with an increase in the magnetic field strength the average growth and its standard deviation are increasing and hence indicating a linear or a positive relationship between the two variables.

 **PROCESSED DATA:**

Now let us evaluate the relationship between the two variables. First, we will explore the relationship between the number of seeds germinated and the magnetic strength of the magnet. The following is the data presented that we will analyse first: -

|  |  |
| --- | --- |
| **MAGNET STRENGTH** |  **FINAL NUMBER OF SEEDS GERMINATED** |
| 0 | 4 |
| 100 | 7 |
| 200 | 13 |
| 300 | 18 |
| 400 | 22 |

A scatterplot will be plotted to and we will run the linear regression to test our hypothesis.

**Figure 1: The relationship between magnet strength vs the seed germinated.**

Hence from the scatterplot we can observe that there is strong linear relationship between the strength of the magnet and the number of seeds generated. The linear relationships after running the linear regression in the excel worksheet, the equation is the following: -

**y = 0.047x + 3.4**

From the equation we can indicate is that with an increase of the magnetic strength the height of the plant increases in the same time span. The y intercept is 3.4 which means indicates our control variable measurement and it is accurate. To test the validity of the results there is a computer-generated R squared value which is: -

**R² = 0.9915**

The R square value is very close 1 and hence the validity of the regression to an largely acceptable extent. Hence, we can confirm our hypothesis. We can also perform the Pearson Correlation Coefficient to test the relationship between the two variables. The formula for the Pearson Correlation Coefficient is denoted by R is:-

$$r=\frac{\sum\_{1}^{5}(L\_{i}-\overbar{L\_{i}})(T\_{i}-\overbar{T\_{i}})}{\sqrt{\sum\_{1}^{5}(L\_{i}-\overbar{L\_{i}})^{2}\sum\_{1}^{5}(T\_{i}-\overbar{T\_{i}})^{2}}}$$

r= Pearson Correlation Coefficient

L= The strength of the magnet

$\overbar{L\_{i}}$= Average of the strength of magnet

T= Number of seeds germinated

$\overbar{T\_{i}}$= Average of the number of seeds germinated

To calculate the Pearson Correlation Coefficient, the values

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **L** | **T** | L-$\overbar{L\_{i}}$ | **T-**$\overbar{T\_{i}}$ | (L-$\overbar{L\_{i}}$)( **T-**$\overbar{T\_{i}}$) | $$(L-\overbar{L\_{i}})^{2}$$ | $$(T-\overbar{T\_{i}})^{2}$$ |
| 0 | 4 | -200 | -8.8 | 1760 | 40000 | 77.44 |
| 100 | 7 | -100 | -5.8 | 580 | 10000 | 33.64 |
| 200 | 13 | 0 | 0.2 | 0 | 0 | 0.04 |
| 300 | 18 | 100 | 5.2 | 520 | 10000 | 27.04 |
| 400 | 22 | 200 | 9.2 | 1840 | 40000 | 84.64 |
| $\overbar{L\_{i}}$=200 | $\overbar{T\_{i}}$=12.8 |  |  | Sum =4700 | Sum = 100000 | 9Sum = 222.8 |

$$r=\frac{4700}{\sqrt{100000×222.8}}$$

$$r=0.9957$$

As we can see that the sign of the Pearson Correlation Coefficient is positive and hence the hypothesis is again strong and the relationship between the two variables is very strong as the coefficient is very close to 1.

Now let us explore the second variable in the experiment which is the shoot length and the strength of the magnet and hence we can list it as follows: -

|  |  |
| --- | --- |
| **MAGNET STRENGTH** | **FINAL LENGTH OF THE SHOOT** |
| 0 | 0.5cm  |
| 100 | 1.9cm |
| 200 | 2.7cm |
| 300 | 3.2 cm |
| 400 | 4.4cm |

Let us plot the two variables on a scatterplot to test our hypothesis. The following is the scatterplot.

**Figure 1: The relationship between magnet strength vs the length of the plant after 5 weeks**

We can see that in the scatterplot above the linear hypothesis is tested. A linear regression was run in excel and we got the following equation for the best fit line: -

**y = 0.0091x + 0.72**

As we can see that the Y intercept of the above equation is 0.72 cm which is correct in terms of our initial control test. And the slope of the line suggests that with an increase of 1 gauss leads to 0.0091 cm increase in the length of the shoot measured over five weeks. Now to test the validity of the model we can test the R squared value:-

**R² = 0.9752**

Hence the R square value is positive and confirming our linear hypothesis and the value is very close to 1 which tells us that the linear regression is very accurate and corresponds the data.

Now the same statistical test of the Pearson Correlation Coefficient will be performed. to test the hypothesis: -

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **L** | **T** | L-$\overbar{L\_{i}}$ | **T-**$\overbar{T\_{i}}$ | (L-$\overbar{L\_{i}}$)( **T-**$\overbar{T\_{i}}$) | $$(L-\overbar{L\_{i}})^{2}$$ | $$(T-\overbar{T\_{i}})^{2}$$ |
| 0 | 0.5 | -200 | -2.04 | 408 | 40000 | 4.1616 |
| 100 | 1.9 | -100 | -0.64 | 64 | 10000 | 0.4096 |
| 200 | 2.7 | 0 | 0.16 | 0 | 0 | 0.0256 |
| 300 | 3.2  | 100 | 0.66 | 66 | 10000 | 0.4356 |
| 400 | 4.4 | 200 | 1.86 | 372 | 40000 | 3.4596 |
| $\overbar{L\_{i}}$=200 | $\overbar{T\_{i}}$=2.54 |  |  | Sum =910 | Sum = 100000 | Sum = 8.492 |

$$r=\frac{910}{\sqrt{100000×8.492}}$$

$$r=0.987$$

Hence the Pearson Correlation Coefficient is positive, and this indicates that there is a positive relationship between the two variables. Also, the intensity of the relationship between two variables is strong as the value is very close to 1. Hence our initial hypothesis between the magnetic strength and the shoot length of the plants after five weeks

# Evaluation

|  |  |  |
| --- | --- | --- |
| **Source of Error and its Effect on Results**  | **Significance and Evidence**  | **Improvements** |
| There were some uncertainties while measuring the length with the scale. | I could have processed the uncertainties after knowing the least count of the scale  | I could use an inch tape with a lower least count and hence to eradicate the systematic error.  |
| The strength of the magnetic field was prementioned in the magnet  | I could not confirm the strength of the magnetic field and if there was any error. | We could use a magnetic flux calculator to test the strength and take the average after performing five trails  |
| There might be random error in the process of measuring the length of the shoot every week for five weeks  | This might be the reason for the slight regression value and the Pearson Correlation coefficient and  | Each week, I should have taken 5 readings for each length and then take the average.  |
| The data spread was very low and the different of the independent variable was very less | We couldn’t have spotted if there was any other relationship in the variables and it could have hidden the overall relationship between the two variables.  | We could use a bigger difference between the strength of the magnetic field and other plants. |

|  |  |
| --- | --- |
| **Strength of the Experiment**  | **Effect**  |
| There was a significant time length which was five weeks | It validated the data and gave us the data to test the linear regression |
| The background information was laid out so that we could accurately predict our results | We could plot graphs and conduct satirical tests which were relevant to the relationship between the two variables. |
| The best fit line passed through almost all the points and hence the data collected from the experiment we performed was valid |  |

# Conclusion

The exploration started with me laying down the background information of the topic and making a viable hypothesis to test. The background information indicated that there is a linear relationship between the magnetic field strength and the length of the shoot and another variable which is the number of seeds which germinate.

The results were promising, and the linear regression yielded good results, and these are the equations of the two regression models. The first one indicates the relationship between magnetic field and the number of germinated seeds and the second one relates to the length of plant.

**y = 0.047x + 3.4**

**y = 0.0091x + 0.72**

There are many extensions of the experiment like testing different plants for the experiment and testing it for a longer length. But given the limitations of time and resources, I was able to conduct a viable experiment to conduct my IB internal assessment biology experiment.

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