The Effect of Static Magnetic Fields on the Growth of Wheatgrass

Introduction:

Starting as early as 200 B.C with the famous Greek physician Galen, numerous scientific studies have investigated the effects of magnetism on organisms and the field is now known as *biomagnetism*.[1] In 1936, Dr Albert Roy Davis theorised that the North and South poles of a magnet consist of different energies with opposite effects on organisms - the South Pole promoted growth while the North Pole retarded it.[2] This idea was not accepted by the scientific community as it was classified as *pseudoscience;* a collection of beliefs or practices that is not based on the scientific method (Merriam Webster, 2013). Previous experiments conducted on plants grown with magnetic fields in their presence indicated better growth (a 20-40% increase), healthier characteristics and a higher germination rate than for those grown in the absence of a magnetic field.[3] However, more research into the effects caused by different polarities and strengths of the magnetic fields is required. Although several theories have been raised to explain how magnetism increases the growth of plants, there currently is no agreement between scientists. The four main proposed theories for this phenomenon are:

- The principle of *MHD (Magneto-Hydro-Dynamics)* where magnetism supposedly reduces the surface tension of water, thus increasing solubility and promoting growth.[4]
- The subtle change in soil temperature caused by electro-magnetic fields which accelerate plant metabolism.[5]
- The attraction of iron particles and starch grains by magnets; stimulating plant growth (fig. 1)
- The excitement of Calcium ions (Ca^{2+}) by magnetic fields which are essential to many areas of plant growth and development. [6]

The chosen species of plant for this experiment was the cereal grain Wheatgrass *(Triticum aestivum)* and the chosen magnets were Iron magnets and Neodymium magnets ($Ne_2Fe_{14}B$)[7] for the weak and strong fields respectively. Wheatgrass is the *cotyledon* (the embryonic first leaves of a seedling) of the common wheat plant (Is Wheat Grass Wheat?, Barbara D Allan, 2011) and there are several reasons for its selection:

- It reproduces asexually and genetically, is almost identical. Hence, the changes are more likely to be a result of the independent variable being tested (the type of magnetic field).
- It grows rapidly, allowing numerous trials to be conducted in a small timeframe.
- The plant grows straight up as a blade of grass allowing accurate height measurements as interfering structures such as leaves are absent.
- Wheatgrass is grown in households for its nutritional benefits and its adult form is traded globally more than every other crop combined[8], making methods to accelerate its growth highly significant to the community.
- If it can be scientifically proven that static magnetic fields do indeed have a significant effect on the growth of wheatgrass, the plant will be a gateway to testing effects on other crops.

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[1] WRF, “Magnetic Effects on Living Organisms” Web. 2008.
[2] Magnetic Therapy, “Effect of magnetism on seeds and Plants” Web. 2010.
[3] Majid, Ahmad.“Effect of Seed Pretreatment by Magnetic Fields on Seed Germination of Agricultural Plants” 2009.
[4] Mundimex, Inc, “MAGNETISM IN AGRICULTURE” Web. 2005.
[5] Kirkham MB, PubMed, “Water relations, temperature, and growth of wheat grown with magnets” 1982. Web.
[6] Casper, Julie Kerr (Ph.D) “PLANTS: Life from the Earth” InfoBase Publishing, 2007, Print.
[7] K&J Magnetics “Neodymium Magnet Safety” Web. 2010.
[8] Farmers Weekly, “World Wheat Crop To Be Third Largest Ever." Web. 2010.

The permanent magnets used were both approximately the same size and shape, however, the iron magnet was made of seven magnets stacked on top of each other so that its height corresponded to the neodymium magnet's. The strength of the iron magnets' magnetic field is estimated to be 500 Gauss (0.05 Tesla) while the Neodymium magnet generates a magnetic field of approximately 10,000 Gauss (1 Tesla).[9] For comparison, the Earth's natural magnetic field which may have an effect on plants is around 0.5-1 Gauss (0.00005-0.0001 Tesla) (What is the Strongest Magnetic Field Ever Known?, Dr Sten Odenwald, NASA Universe).

Aim:

This experiment aims to prove that static magnetic fields do have an impact on plant growth, to settle the dispute of the effects of different polarities via the scientific method and to find the best combination of strength and polarity to promote growth in Wheatgrass.

Hypothesis:

The stronger the magnetic field, the faster the growth of the plant. The polarity of the magnets should not have an effect on growth.

Materials:

- Plastic drinking cups (5)
- Plastic desert bowls (5)
- Neodymium Magnets – radius 1cm height 2.5cm (2)
- Iron Magnets – radius 1cm height 0.35cm (14)
- Plastic drinking cup filled halfway with soil (5) (20tbsp. Soil)
- Whole wheat (2 tbsp.)
- 750 mL Glass Jar (1)
- Strainer (1)
- Tweezers (1)
- Spray bottle filled with water (1)
- Permanent Marker (1)
- Ruler calibrated to mm (1)
- Wooden Chopstick (1)
- Pen (1)
- Thick Gloves (1)
- Safety Glasses (1)

Risk Assessment:

Hazardous Item	Potential Hazard	Safety Precaution
Mould	Can grow on Wheatgrass	Discard seeds affected by mould safely by wrapping them in tissue.
Neodymium Magnet	Can severely pinch fingers or other body parts between two magnets.	Handle magnets with great care and wear thick gloves.
Neodymium Magnet	Can shatter when one magnet slams into another.	Avoid contact between magnets and wear eye protection.

[9] CMS Magnets, "Magnet Basics" Web. 2007

Method:

Day 1

1. Placed 2 tbsp. of whole wheat in a glass jar.

2. Filled the jar with 250mL of water and left it to soak for 12 hours.

Day 2 - 4

3. Rinsed the seeds and then left the seeds in the jar without water.

4. Repeated previous step every 12 hours for four more times.

Day 4-9

5. Picked out 20 sprouts in the jar with similar stem heights (1.5cm) using tweezers.

6. Planted four of these sprouts in each of the five soil filled cups.

7. Placed each magnet 30cm away from each other in a line, in an area with equal indirect sunlight.

8. Centred an upturned plastic desert bowl over each magnet and placed an additional bowl for the control. (See experiment setup p.9)

9. Positioned the soil filled cups with sprouts on the centre of each upturned desert bowl

10. Labelled each cup and bowl with a permanent marker as Strong South, Strong North, Weak South, Weak North or Control.

11. Watered plants every 12 hours – one spray to the base of each plant - and recorded the height every day for six days using the calibrated chopstick (made with a pen and mm ruler - see fig.4).

Four plants were planted in each cup to increase the sample size and acquire averages. Three trials were then conducted and the averages of their averages used to further increase reliability. The experiment can be replicated easily and each trial can be performed in nine days. This allows for repetition to acquire valid, reliable results. The control is set up exactly as the other four cups except that there is no magnet inside the overturned desert bowl. The independent variable was the type of magnetic field, the dependent variable the height of the plant and the controlled variables were the environmental factors.

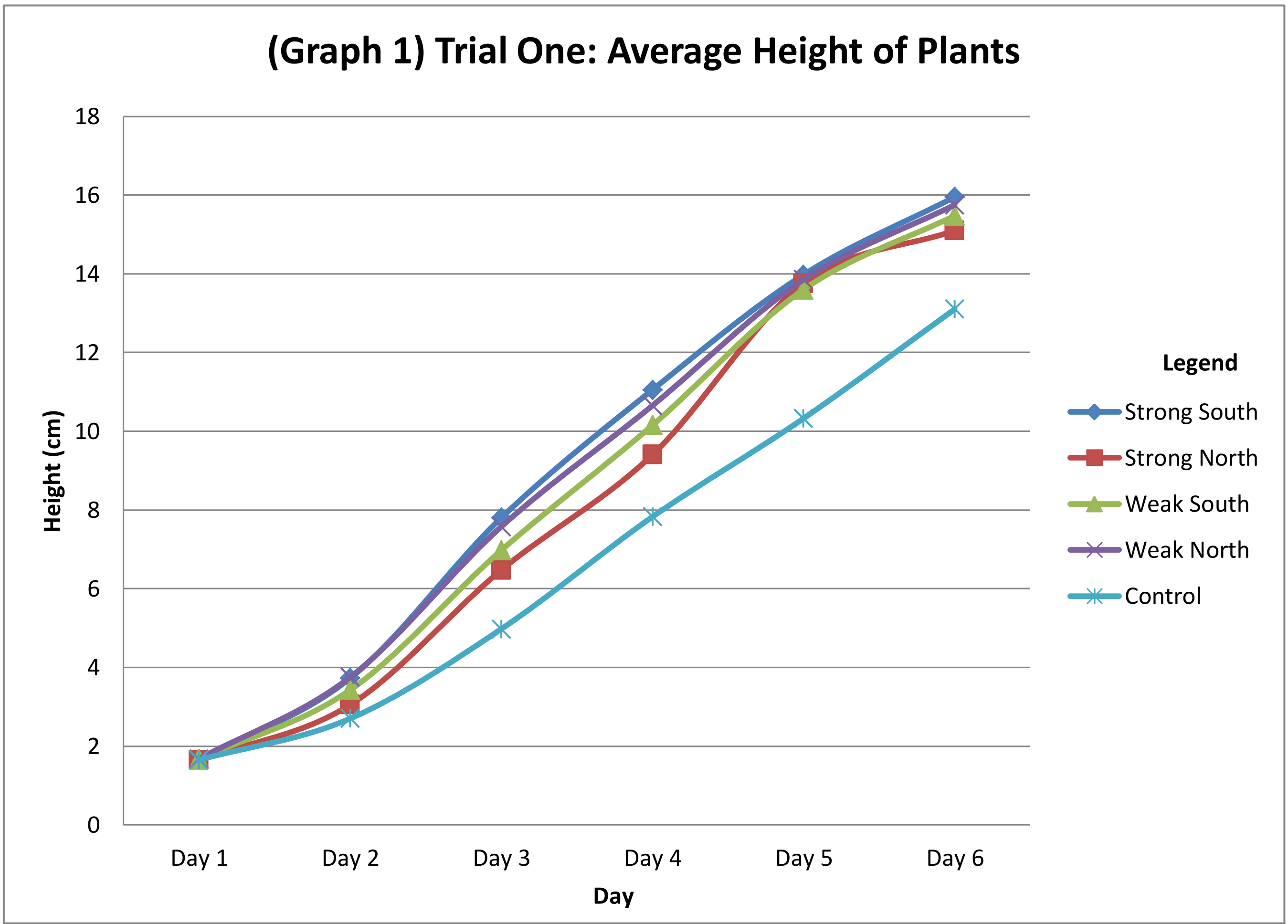
Results:

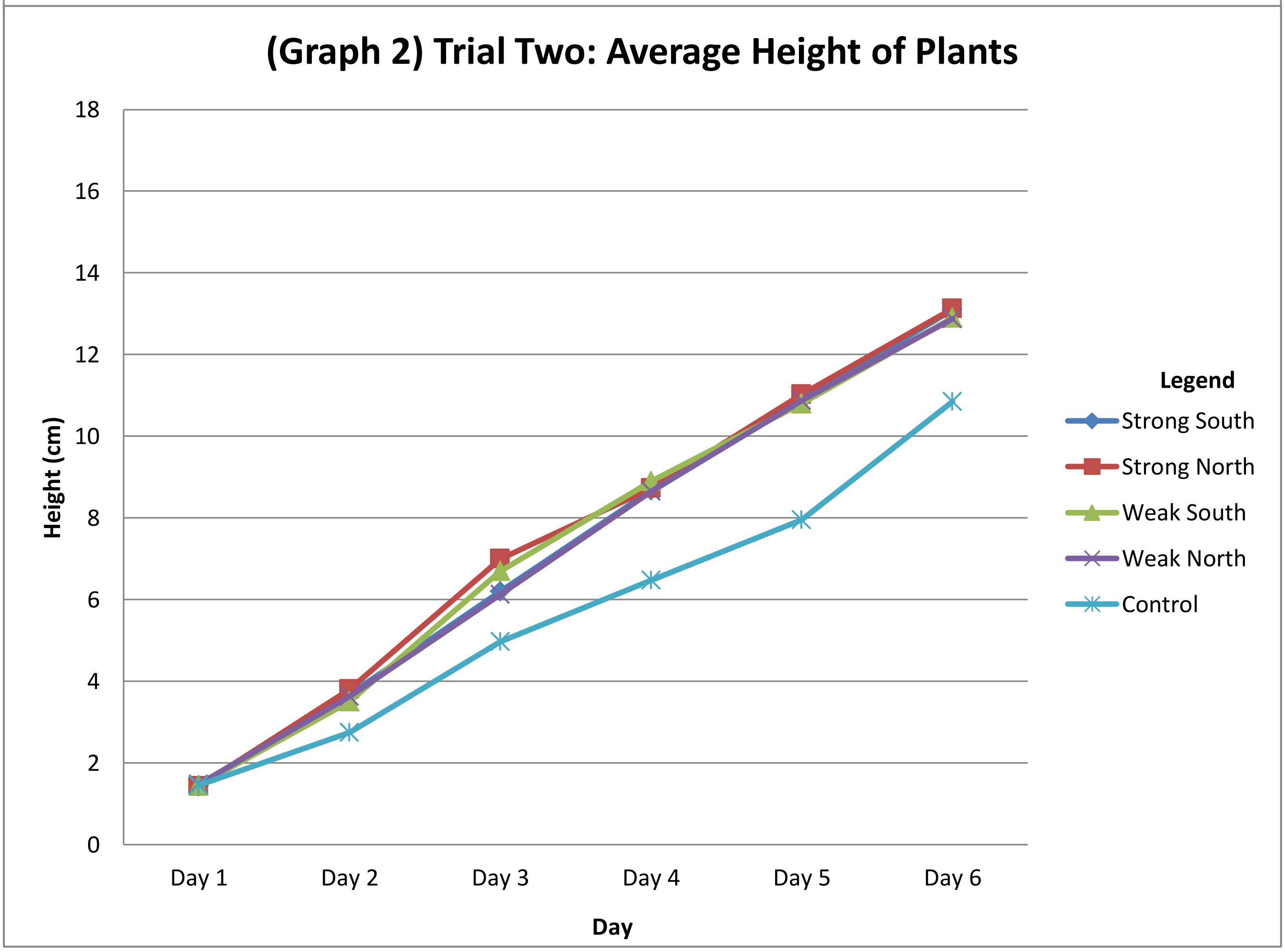
<Refer to results booklet for raw data>

Statistical comparison between control and types of magnetic fields (Paired *t* test).

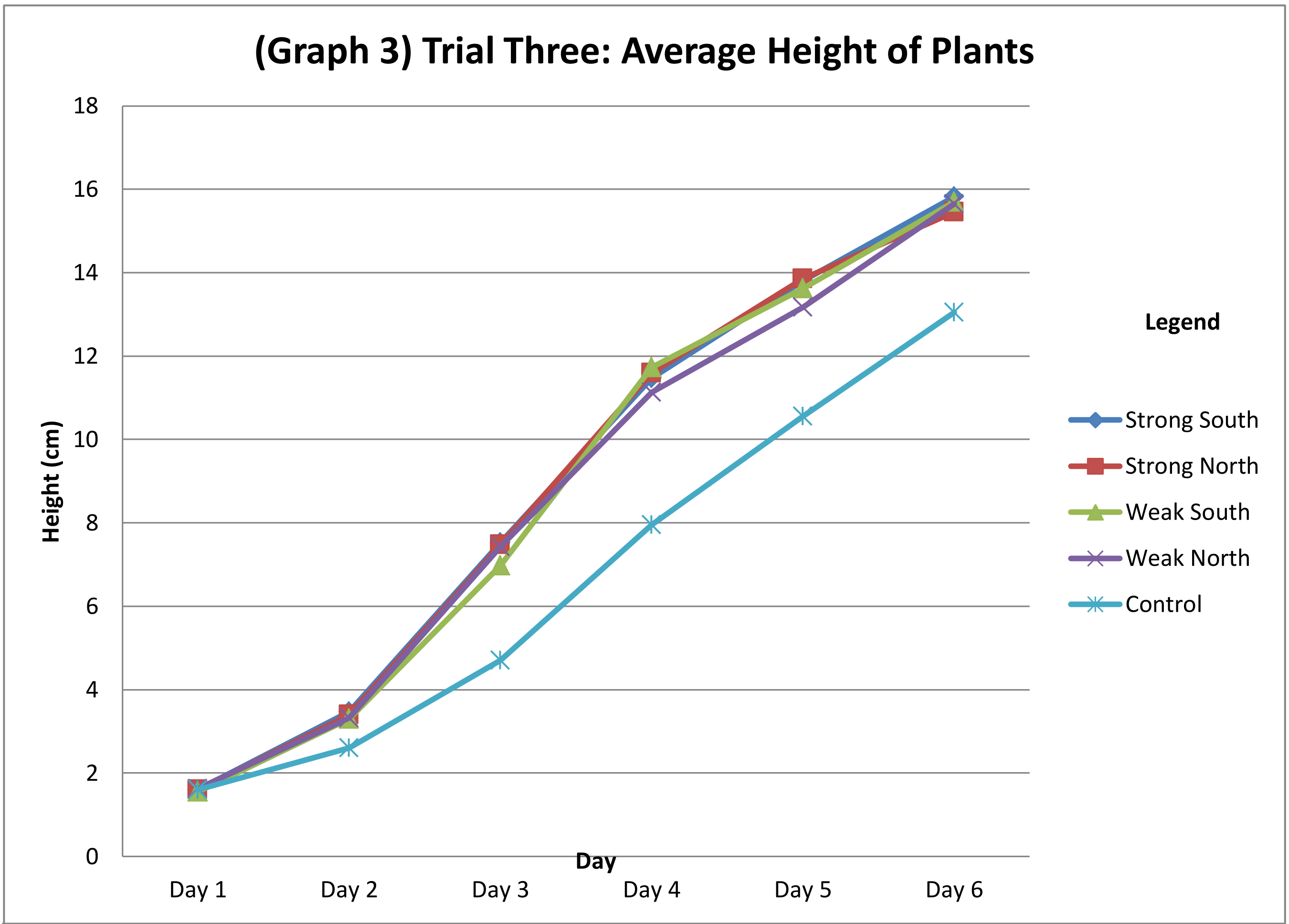
Comparison	***t* Value**	***P* Value**	**Significance**
Control vs. Strong South	3.8260	0.0123	Yes
Control vs. Strong North	3.6265	00151	Yes
Control vs. Weak South	3.6434	0.0149	Yes
Control vs. Weak North	3.9055	0.0113	Yes
Strong South vs. Strong North	0.3953	0.7089	No
Weak South vs. Weak North	0.2774	0.7926	No
Strong South vs. Weak South	0.5423	0.6109	No
Strong North vs. Weak North	0.6202	0.5623	No

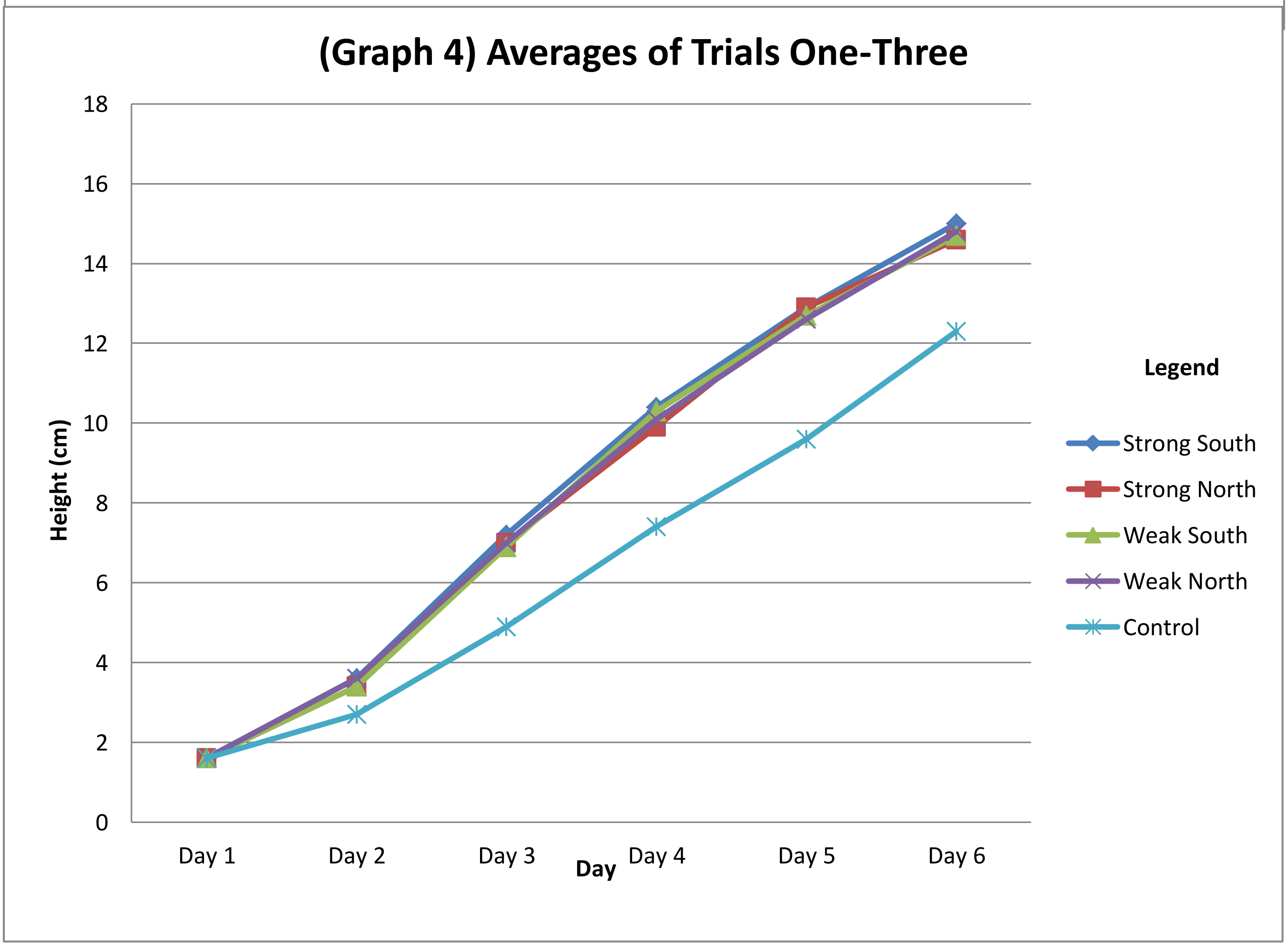
Graphs


(Graph 1) Trial One: Average Height of Plants
Height (cm)
0
2
4
6
8
10
12
14
16
18
Day 1
Day 2
Day 3
Day 4
Day 5
Day 6
Day
Legend
Strong South
Strong North
Weak South
Weak North
Control


(Graph 2) Trial Two: Average Height of Plants
Height (cm)
0
2
4
6
8
10
12
14
16
18
Day 1
Day 2
Day 3
Day 4
Day 5
Day 6
Day
Legend
Strong South
Strong North
Weak South
Weak North
Control

Graphs (continued)





Overview

All four plants grown in the presence of the artificial, static magnetic field have grown significantly higher than the control. However, when the averages of all three trials are taken there is no considerable difference between the types of magnetic fields. The anomalies for particular magnetic fields in some of the trials may have been due to some uncontrolled variables, nevertheless, the execution of three trials ensured that these irregularities were not taken into account. Although the difference in height between the plants grown in a magnetic field and the control did get larger from days one-five, the relative difference to the control decreased i.e. the average difference between the control and the magnet group was 30% on Day Two and decreased to 20% by Day Six. This trend can be expected to continue as the plants grow.

Discussion:

The results of this experiment has proved that static magnetic fields do have a significant impact on the growth of Wheatgrass and also disproves that polarities of magnets have separate effects on plants. It also demonstrates that when the strength of the magnetic field exceeds approximately 500 Gauss, the height of Wheatgrass does not increase along with it. The statistical comparison demonstrates that the difference in heights between the control and all magnetic fields is statistically significant, however, the differences between the field strengths and polarities are not statistically significant.

The general trend obtained from the data is that all four types of magnetic fields will improve plant growth equally and that the relative difference in height between plants exposed to magnetic fields and those that are not exposed to magnetic fields decreases over time. This suggests that if the plants are given enough time, the control will approach the height of the plants exposed to a magnetic field, albeit taking a longer time to reach this height. By using the scientific method, the experiment has disproved the pseudoscience which claims that South and North poles of magnets are different energies and have particular effects on all organisms, as all plants subject to North and South ends exhibited the same level of growth (as indicated by Graph 4). If this claim was true, plants subject to the 'South fields' would show significantly better growth and those exposed to the 'North fields' would show suppressed growth. The original hypothesis was that the stronger the magnetic field was, the greater the growth, yet the results display that magnetic fields greater than 500 Gauss (0.05 Tesla) do not stimulate extra growth. These results complement the findings of Vashisth A and Nagarajan S. who in their investigation titled '*Exposure of seeds to static magnetic field enhances germination and early growth characteristics in chickpea (Cicer arietinum L.)*' state that "…the response varied with field strength without any particular trend." This could be a consequence of a certain threshold under 500 Gauss for the strength of the magnetic fields after which the plants stop increasing in height and an experiment with many varying levels of weak field strengths are required to test this explanation.

Although there is no agreement in the scientific community to explain how magnetism promotes the rise in plant growth, the results of this experiment can be used to find the most plausible explanation out of the four presented theories. The principle of Magneto-Hydro-Dynamics (reducing the surface tension of water using magnets) is extremely unlikely to be the cause of the increased growth since the principle applies mainly to gaseous plasmas and not aqueous solutions. The theory is in fact tossed around by 'magnet merchants' who claim this to be the reason for increased plant growth by their 'specialised' magnets. This theories' relation to water and plant growth is thoroughly debunked by Stephen Lower from the Dept. of Chemistry of Simon Fraser University in his web article *'Magnetic Water Treatment and Pseudoscience'.*

The next theory has been proposed by Kirkham MB and Hartmann GH, who attribute the faster growth of wheat in their experiment titled *'Water relations, temperature, and growth of wheat grown with magnets'* to an increased soil temperature. The wheat that was exposed to magnetic fields was 0.5^{o} C warmer than the control and was also larger. Consequently, they concluded that the increased height and dry weight was a result of this subtle change in temperature caused by the magnet, stimulating growth. However, Kirkham MB and Hartmann GH used electromagnets of varying ampere-turns in their investigation which generate waste heat as the electrical current passes through the copper coils. The magnets used in this experiment were permanent magnets and were not rotated. As a result, they did not generate heat.[10] It is also unlikely that a 20%+ increase in growth could be a result of such a subtle change in temperature.

The third theory speculates that the increase in growth may be a result of starch grains and/or iron particles in plant cells being attracted by the magnet, as illustrated by fig. 1. As the starch grains and iron particles are attracted by the magnet, the plants would be inclined to grow towards that direction. This could be plausible if the magnet was placed above the plants, were the force of the starch grains and iron particles being attracted upwards could encourage and provide support for the plants to grow upwards. However, in this experiment the magnets were placed below the plants, hence, this theory does not explain the increased growth.

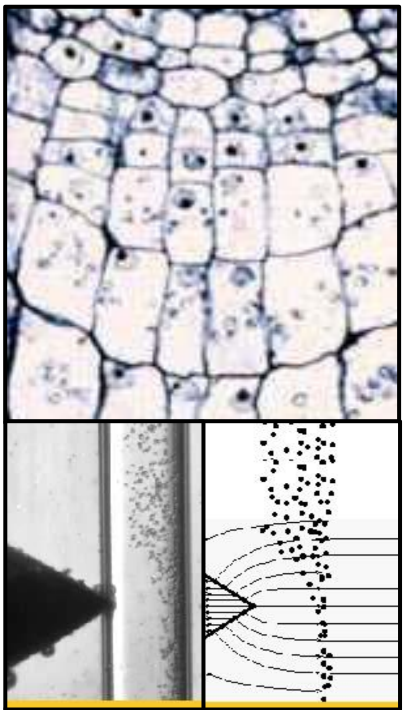


Figure 1

Top: Starch Grains in a plant cell

Bottom: Starch grains being repelled by a high-gradient magnet.

(Image Courtesy: NASA)

The most plausible theory that explains the increased growth of the plants in this experiment would have to be the excitement of calcium ions (Ca^{2+}) in plants by magnetic fields. Calcium ions are structural nutrients required for the formation of new cells and are essential to many areas of plant health.[11] This theory was proposed by bio-magnetic researcher Jim Lang (Wilmington Star News, 20th March, 1977) and many others. Lang explains that the ions in plant food and water carry an electrical charge and flow along the Earth's magnetic lines and that a properly placed magnet allows the food and water to flow to the plants' growing cells faster. In an investigation conducted by Belyavskaya NA titled *'Biological effects due to weak magnetic fields on plants'* cyto-chemical studies (the study of chemical composition and activity of cells) revealed a significantly higher concentration of Ca^{2+} in all organelles and mitochondria were larger in size and in relative volume in cells to the control group. This is conclusive evidence for the role of magnetic fields in increasing the circulation of Calcium ions. Therefore, this theory is the most plausible explanation for the stimulated growth of plants by static magnetic fields in this experiment. However, Belyavskaya also reported Ca^{2+} over-saturation in his flax and lentil roots which inhibited growth, suggesting that not all plant species would benefit from exposure to magnetic fields.

The method used by this investigation was highly reliable, as it used a large sample size of four plants per type of magnetic field and the trial was repeated a total of three times. The trials had very similar results which proves that the method was reliable. This was because of a variety of variables that were controlled including:

[10] Welch, Kevin. Radialogical Controls Group. "Do rotating magnets create energy?" Web. 2008.
[11] Nutrient Technologies, "Essential Plant Nutrients and their Functions" Web. 2009.

- Size of cup (same cups used)
- Amount of water per plant (one spray to the base of each plant)
- Air temperature (room temperature, open environment)
- Seeds used (Wheat)
- Sprout starting heights (all sprouts were physically similar and started at approximately 1.5cm)
- Amount of Light (indoors, equal amount of diffused light)
- Medium used (soil, evenly mixed in a tray)
- Distance between plants and magnetic field (magnets are the same size, under cups)

Accuracy was ensured as a mm ruler was used and was accurately transcribed onto a chopstick. The chopstick was necessary as the ruler would not fit in the cup easily and would disturb the plants. The height mesured for the plants was taken by lightly pulling the blade of grass to straighten it. This could have been improved by using a flexible ruler and would also cause less disturbance to the plant. Overall, the results are very reliable and accurate, especially for the average of trials one-three as it excludes all the anomalies from individual trials.

The experiment could be improved by making several differences. Firstly, the measure for the strength of the magnetic fields was approximated using averages provided from many sources for different types of magnets. If electromagnets were used, many varying levels of magnet strengths could be used and the strength of the fields could be meausured in ampere-turns.[12] Secondly, measuring more parameters of the wheat plant at the end of the trial such as weight and root length could have also provided interesting data. Further research can also be conducted on how different plant species respond to magnetism.

The results of this experiment are highly significant to the community, as it shows a substantial 20% increase in plant height with the introduction of a weak magnetic field. The investigation proves that powerful, expensive magnets are not neccesary to stimulate growth, making the method more economically viable for comercial use. Cheap iron magnets can be used by home-growers of wheatgrass to allow faster growth. However, implementing this in large-scale agriculture would be rather difficult and simply spreading magnets over agricultural land would be impractical. Thus, magnets are more suited for use in plant nurseries, when growing herbs, and gardening at home. It can also be effectively utilised in the new generation of sustainable, vertical, indoor farms (fig. 2) to increase productivity, where profits from the extra gains in plant mass would offset the cost of magnets. With a growing world population and land increasing in value, vertical indoor farms with improved productivity via the use of magnetic fields could be the solution for the future.

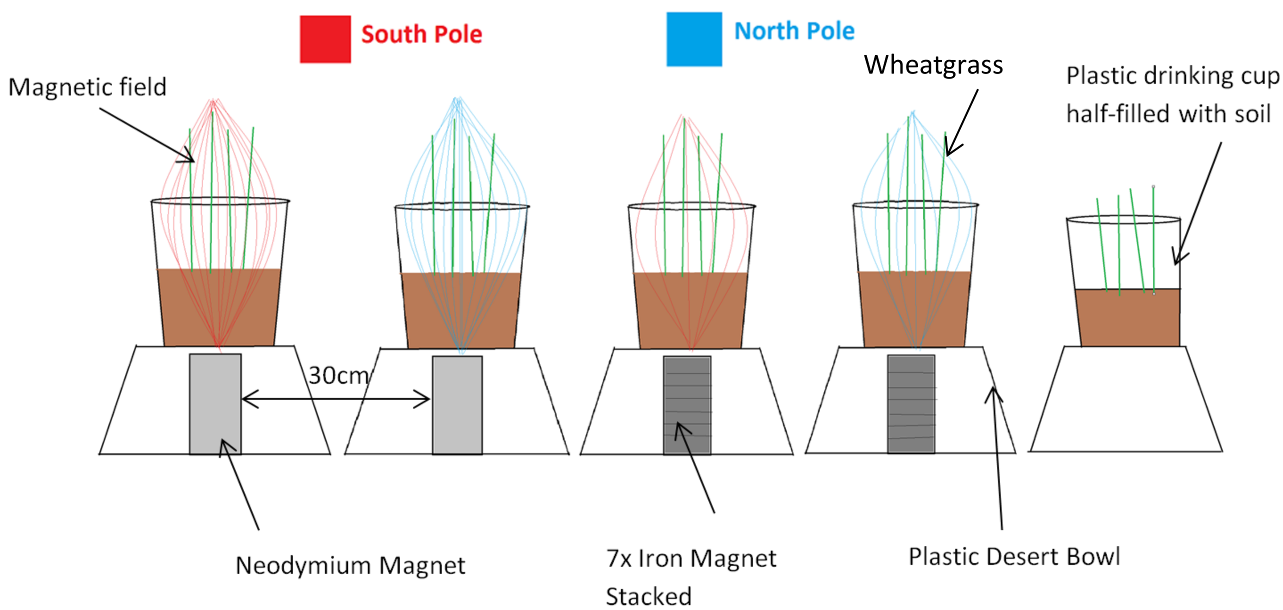
Figure 2: An indoor, urban, vertical farm in Singapore that would benefit from the use of weak magnetic fields.

[12] Kirkham MB, Hartmann GH, PubMed, “Water relations, temperature, and growth of wheat grown with magnets” 1982. Web.

Conclusion:

The experiment proved that static magnetic fields do have a significant positive impact on the growth of wheatgrass (a 20%+ increase), disproved the pseudoscience that claimed the North and South poles of a magnet have different effects on organisms and demonstrated that magnets stronger than 500 Gauss (0.05 Tesla) are not necessary to stimulate this increased growth. Plants showed an equal amount of increased height, whether the magnetic field was of North or South polarity or if the magnets were measured at 500 or 10,000 Gauss. This difference between the control group and the group exposed to magnetic fields was always statistically significant. The most likely explanation for the promotion of growth by magnetic fields was found to be the excitement of calcium ions. It was also suggested that Iron magnets could be utilised to increase productivity in indoor farms and used by home-growers for faster growth. Further research into the plant species that would benefit the most from static magnetic fields and the minimum magnetic strength required for the increase in growth is required.

Experiment Setup



Panoramic view of experiment; actual layout is straight with equal distance between cups.

Comparison of height between three groups in the later stages of trial two.

<-The 'calibrated chopstick'.

Comparison of sizes of neodymium and iron magnets.

Whole wheat and five cups.

Left: Wheat Sprouts in jar.

Right: 20 identical sprouts

Top: Preliminary Trial 1

Bottom: Preliminary Trial 2

Top: Straining seeds for Pre. trial 2

Bottom: Strong South, Day 3, Trial 1

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Results Booklet (Raw Data)

Trial One

Type of Magnetic Field	Stem Heights (cm)	Average Height (cm)
Day 1		
Strong South Field	1.8, 1.6, 1.7, 1.6	1.675
Strong North Field	1.7, 1.6, 1.7, 1.6	1.650
Weak South Field	1.8, 1.5, 1.8, 1.6	1.675
Weak North Field	1.7, 1.5, 1.7, 1.8	1.675
Control	1.9, 1.6, 1.6, 1.5	1.650

Day 2		
Strong South Field	3.3, 4.4, 4.5, 2.5	3.725
Strong North Field	2.9, 3.9, 2.3, 3.1	3.05
Weak South Field	4.4, 3.9, 3.1, 2.6	3.425
Weak North Field	4.6, 3.6, 4.5, 2.3	3.75
Control	4, 1.8, 2.6, 2.4	2.7

Day 3		
Strong South Field	9, 6.1, 7.5, 8.6	7.8
Strong North Field	6.3, 8, 5.2, 6.4	6.475
Weak South Field	7.7, 6.5, 7, 6.7	6.975
Weak North Field	8.6, 7.2, 8.5, 6	7.575
Control	6.9, 2.8, 6, 4.2	4.975

Day 4		
Strong South Field	12.4, 10.5, 11.6, 9.7	11.05
Strong North Field	9.1, 11, 9.4, 8.1	9.4
Weak South Field	9.6, 10.9, 10.4, 9.7	10.15
Weak North Field	11.7, 10.3, 12, 8.6	10.65
Control	10.3, 9.2, 6.6, 5.2	7.825

Day 5		
Strong South Field	15.3, 13.6, 14.2, 12.8	13.975
Strong North Field	12.7, 15.8, 13.6, 12.9	13.75
Weak South Field	13.1, 15.2, 13.3, 12.8	13.6
Weak North Field	16.2, 13.2, 14.1, 11.9	13.85
Control	12.7, 11.4, 9.1, 8.3	10.325

Day 6		
Strong South Field	17.4, 14.6, 15.7, 16.1	15.95
Strong North Field	17.1, 14.1, 14.5, 14.7	15.1
Weak South Field	15.7, 16.3, 15.6, 14.3	15.475
Weak North Field	18.5, 16.3, 15.8, 12.4	15.75
Control	15.5, 9.7, 15.9, 11.3	13.1

Trial Two

Type of Magnetic Field	Stem Heights (cm)	Average Height (cm)
Day 1		
Strong South Field	1.5, 1.3, 1.4, 1.5	1.425
Strong North Field	1.6, 1.4, 1.4, 1.3	1.425
Weak South Field	1.6, 1.3, 1.5, 1.4	1.45
Weak North Field	1.5, 1.5, 1.5, 1.3	1.475
Control	1.6, 1.7, 1.3, 1.3	1.45

Day 2		
Strong South Field	4.1, 3.3, 3.4, 3.9	3.675
Strong North Field	4.3, 3.8, 3.1, 3.5	3.8
Weak South Field	3.5, 4.2, 3.7, 3.2	3.5
Weak North Field	3.7, 3.3, 3.5, 4	3.625
Control	2.3, 3.2, 2.7, 2.9	2.75

Day 3		
Strong South Field	7.7, 5.7, 5.3, 6.1	6.2
Strong North Field	7.9, 6.7, 6.3, 7.1	7
Weak South Field	5.6, 7.4, 7.2, 6.6	6.7
Weak North Field	6, 5.7, 6.1, 6.7	6.125
Control	4.3, 6.3, 5.1, 4.2	4.975

Day 4		
Strong South Field	9.5, 7.9, 8.2, 9.1	8.675
Strong North Field	9.9, 8.4, 7.4, 9.2	8.725
Weak South Field	8.4, 9.7, 9.3, 8.2	8.9
Weak North Field	9.2, 8.7, 7.8, 9.3	8.65
Control	6.7, 7.3, 6.1, 5.8	6.475

Day 5		
Strong South Field	11.7, 10.1, 10.3, 11.4	10.875
Strong North Field	12.2, 10.8, 9.4, 11.5	11.025
Weak South Field	10., 11.8, 11.1, 9.7	10.8
Weak North Field	11.4, 10.8, 9.9, 11.4	10.875
Control	8.7, 9.1, 7.6, 6.4	7.95

Day 6		
Strong South Field	13.9, 12.4, 12.8, 13.3	13.1
Strong North Field	14.3, 13, 11.9, 12.9	13.125
Weak South Field	12.6, 13.4, 13.9, 11.7	12.9
Weak North Field	12.8, 12.3, 11.7, 14.7	12.875
Control	10.6, 10.3, 11.3, 11.2	10.85

Trial Three

Type of Magnetic Field	Stem Heights (cm)	Average Height (cm)
Day 1		
Strong South Field	1.7, 1.6, 1.5, 1.6	1.6
Strong North Field	1.5, 1.5, 1.8, 1.6	1.6
Weak South Field	1.6, 1.6, 1.5, 1.6	1.575
Weak North Field	1.7, 1.5, 1.7, 1.6	1.625
Control	1.5, 1.8, 1.5, 1.6	1.6

Day 2		
Strong South Field	3.7, 3.2, 4.1, 2.9	3.475
Strong North Field	3.4, 3.5, 3.1, 3.6	3.4
Weak South Field	3.2, 2.8, 3.7, 3.5	3.3
Weak North Field	4.3, 3.2, 3.1, 2.9	3.325
Control	3, 2.7, 2.3, 2.4	2.6

Day 3		
Strong South Field	7.7, 7.4, 8.1, 6.9	7.525
Strong North Field	7.5, 7.8, 6.8, 7.8	7.475
Weak South Field	6.7, 6.9, 7.3, 7	6.975
Weak North Field	7.4, 6.6, 8.2, 7.5	7.425
Control	5.3, 4.8, 4.1, 4.7	4.7

Day 4		
Strong South Field	11.4, 12.1, 12.3, 11.1	11.475
Strong North Field	1.5, 11.7, 11.9, 12.3	11.6
Weak South Field	11.6, 11.9, 10.6, 12.8	11.725
Weak North Field	11.2, 10.4, 11, 11.9	11.125
Control	8.3, 7.8, 8.1, 7.6	7.95

Day 5		
Strong South Field	13.7, 14.3, 14.1, 13.1	13.8
Strong North Field	12.9, 14.5, 14.2, 13.8	13.85
Weak South Field	13.8, 14.1, 12.7, 13.1	13.625
Weak North Field	12.3, 13.4, 12.1, 14.9	13.175
Control	10.4, 9.7, 10.6, 11.5	10.55

Day 6		
Strong South Field	15.2, 16.3, 15.7, 16.1	15.825
Strong North Field	14.8, 16.7, 15.3, 15	15.45
Weak South Field	15.6, 15.9, 15.3, 16	15.7
Weak North Field	16.5, 15.2, 15.5, 15.4	15.65
Control	14.3, 13.2, 11.2, 13.5	13.05

Average of Trials 1-3

Type of Magnetic Field	Average Height (cm) 1 dec. pl.	Avg. of Magnets vs. Control
Day 1		
Strong South Field	1.6	1.6
Strong North Field	1.6	
Weak South Field	1.6	
Weak North Field	1.6	
Control	1.6	1.6
Day 2		
Strong South Field	3.6	3.5
Strong North Field	3.4	
Weak South Field	3.4	
Weak North Field	3.6	
Control	2.7	2.7
Day 3		
Strong South Field	7.2	7.0
Strong North Field	7.0	
Weak South Field	6.9	
Weak North Field	7.0	
Control	4.9	4.9
Day 4		
Strong South Field	10.4	10.2
Strong North Field	9.9	
Weak South Field	10.3	
Weak North Field	10.1	
Control	7.4	7.4
Day 5		
Strong South Field	12.9	12.8
Strong North Field	12.9	
Weak South Field	12.7	
Weak North Field	12.6	
Control	9.6	9.6
Day 6		
Strong South Field	15.0	14.7
Strong North Field	14.6	
Weak South Field	14.7	
Weak North Field	14.8	
Control	12.3	12.3