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The Effects of Neodymium and Ceramic Magnets on the Germination and Growth Rate of Coriander (*Coriandrum sativum*) in *Ex-vitro* Conditions

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ABSTRACT

A magnetic field (MF) is the magnetic effect of an electric current or magnetic material and it can be measured in Tesla (T) or Gauss. In the sixteenth century, scientists observed that magnets could influence plant growth. From that point onward, various experiments have been conducted and results have shown that different strengths in MFs have displayed different morphological and genetic characteristics in different plant species. In some, the effect is growth retardation while others show significant growth. Thus, the main objective of this study was to determine the effects of the MFs from both neodymium and ceramic magnets on the germination and growth rate of coriander seeds. In this experiment, seeds were planted around the magnets three (3) cm away. Three different magnetic fields from both neodymium magnets and ceramic magnets were used. The polarity was also studied where some seeds were subjected to the north pole pointing upwards and others the south pole pointing upwards. Results from the experiments showed that the type of magnets, the strength of the magnetic field and the polarity do influence the germination, and growth rate of coriander. The influence was significant when compared to the control which were seeds sown under the influence of the Earth's Geomagnetic field (GMF) only where all plants grow. This research showed that neodymium magnets had a more positive effect on the growth rate than ceramic magnets. It also proved that the low and medium strengths neodymium magnets with the south pole pointing upwards produced the best growth with significant differences to the other treatments.

Key words: *Coriander, Germination, Neodymium magnet, Ceramic magnet.*

1. INTRODUCTION

A magnetic field (MF) is an inescapable environmental factor for plants on Earth. During the evolutionary process, all living organisms experienced the action of the Earth's geomagnetic field (GMF), which is a natural component of the environment. The natural magnetic field of Earth (50 μT) influences all living organisms (Dhawi, 2014). In 1862, Louis Pasteur discovered that magnetism affects plant growth when he was experimenting on the fundamentals of fermentation. He found that the Earth's magnetism affects the growth of plants, which led to Savostine (1930) being the first person to conduct studies in this field, whereby 100% increase in the rate of elongation of wheat seedling under the influence of a magnetic field was observed (Subber *et al*., 2012). Various research has shown significant differences in the strength and direction of the earth's magnetic field. Thus, plants which are known to sense different wavelengths of light, respond to gravity, react to touch and electrical signaling cannot escape the effects of the GMF. While phototropism, gravitropism, and thigmotropism have been thoroughly studied, the impact of GMF on plant's growth and development is not fully understood (Maffei, 2014).

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There have been studies over the years that state the importance of magnetic fields used as a safe alternative to improve agricultural crops. The most important applications of a magnetic field are the treatments on irrigation water, dry seeds, wet seeds and seedling. Physical treatment of seeds under low magnetic fields is one of the successful methods which has shown to improve the growth and yield of plants like maize (Shine *et al*., 2012). Also, the effect of different magnetic fields varies depending on the plant species and age during exposure (Dhawi, 2014). Magnets can also be used to magnetize water for irrigating crops, which decreases crop cycle by days, and hence crop production increases from 15% to 100%. Plant diseases occurrence dramatically decrease, and the taste of the products improves. Importantly, it can decrease salinity from the soil and no sediment is formed on the soil surface (Rhoades & Van Schilgaarde, 1976).

Coriander acts as a source of dietary fiber, iron, and magnesium. It has vitamin A, C, K, protein, small amounts of calcium, phosphorus, thiamin, niacin and carotene. It is good for diabetes, it lowers bad cholesterol and improves the good cholesterol. The objective of this research is to study the effects of the magnetic fields of neodymium magnets and ceramic magnets (also known as ferrite magnets) on the germination and growth of coriander (*Coriandrum sativum*) in *ex-vitro* conditions.

2. MATERIALS & METHODS

This research was conducted at the Faculty of Science & Technology, University of Belize, Cayo District, Belize C.A. Two different types of magnets were used in this study. The Neodymium (NdFeB) magnets were gotten from computer hard drives as they were inexpensive and accessible and ceramic magnets that were purchased at a local hardware store. The magnetic fields (MF) were measured for the different magnets with a handmade gauss meter in micro-tesla (μT).

Coriander seeds were obtained and a germination test was conducted to determine the viability of the seeds. For the germination test, twenty styrofoam containers measuring 11.3 cm in diameter and 17 cm in height were used and filled with a potting material (Sta-Green potting mix plus fertilizer). This substrate was watered before the seeds were planted, and six coriander seeds were planted at a depth of 1 cm and about 2 cm away from the edges of the containers. Irrigation was carried out on a daily basis. The number of seeds germinated and the time of germination were evaluated.

2.1 The effects of the Neodymium (NdFeB) magnets

This experiment studied three different strengths of the magnet as well as the positions of the north and south poles (Table 1). The magnets were placed in the center of the containers and the seeds were planted around the magnet. Six coriander seeds were used for each container and twenty containers were used for each treatment. These seeds were irrigated on a daily basis. In the first three treatments the north of the magnet was pointing upwards while treatments 4-6 studied the same different strengths magnet, but with their south pole pointing upwards. The control was comprised of seeds planted in the container, however, without any magnets.

Table 1. Description of the experiment with different strengths of neodymium magnets and their position

Treatments	Neodymium magnet & strengths	Position pointing upwards
1	NdFeB (953 μT)	North
2	NdFeB (1,684 μT)	North
3	NdFeB (2,504 μT)	North
4	NdFeB (953 μT)	South
5	NdFeB (1,684 μT)	South
6	NdFeB (2,504 μT)	South

The parameters evaluated were time of germination and growth rate of the seedlings. The number of days germination takes was noted and the height of the plantlets were measured every week for six weeks.

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2.2 The effects of the Ceramic magnets

Ceramic magnets represent approximately 75% of the magnets used in the world today, hence it was important to determine its effects on the growth and development of plants, specifically coriander. It was also important to make a comparison between the two types of magnets.

Three different strengths of ceramic magnets were studied as well as the position of the north and south pole (Table 2). In treatments 1-3, the north pole was pointing in an upward direction, while treatments 4-6 had their south pole pointing in the upwards direction.

Table 2. Description of the experiment with ceramic magnets and their position.

Treatments	Ceramic magnet & strengths	Position pointing upwards
1	Ceramic (850 μT)	North
2	Ceramic (1,506 μT)	North
3	Ceramic (2,485 μT)	North
4	Ceramic (850 μT)	South
5	Ceramic (1,506 μT)	South
6	Ceramic (2,485 μT)	South

The control used in this experiment consisted of seeds planted in the same type of containers; however, without any magnets. The parameters evaluated were time of germination and growth rate of the seedlings. The number of days germination takes was noted and the height of the plantlets were measured every week for six weeks.

2.3 Statistical analysis

The data collected were analyzed using the statistical computer software known as Statistical Package for Social Science (SPSS) and Mega Stats. Analysis of Variance (ANOVA) and Dunnett's test were used, which allowed inferences to be made about the statistical differences between treatments in each of the parameters evaluated.

3. RESULTS & DISCUSSIONS

According to Dhawi (2014) the natural magnetic field of the Earth influences all living organisms. Subber *et al*. (2012) have shown that MFs affect proliferation, cell differentiation, biological activities of corn and the acceleration and/or deceleration of seed germination, changing in flowering time and aging. In the germination test that was carried out in this research, the percentage viability resulted to be 98.3%. This result was very good to carry out the experiment with these seeds.

The effects of the Neodymium (NdFeB) magnets

The time from planting to germination was evaluated in this experiment and the results (Table 3) showed that treatment 5, which was the medium strength neodymium magnet with its south pole pointing upward was the best in terms of the time the seeds take to germinate. Seeds under treatment 5 germinated in 8.1 days and this was significantly lower than all the other treatments including the control.

Table 3. Germination time of coriander seeds subject to neodymium magnetic fields

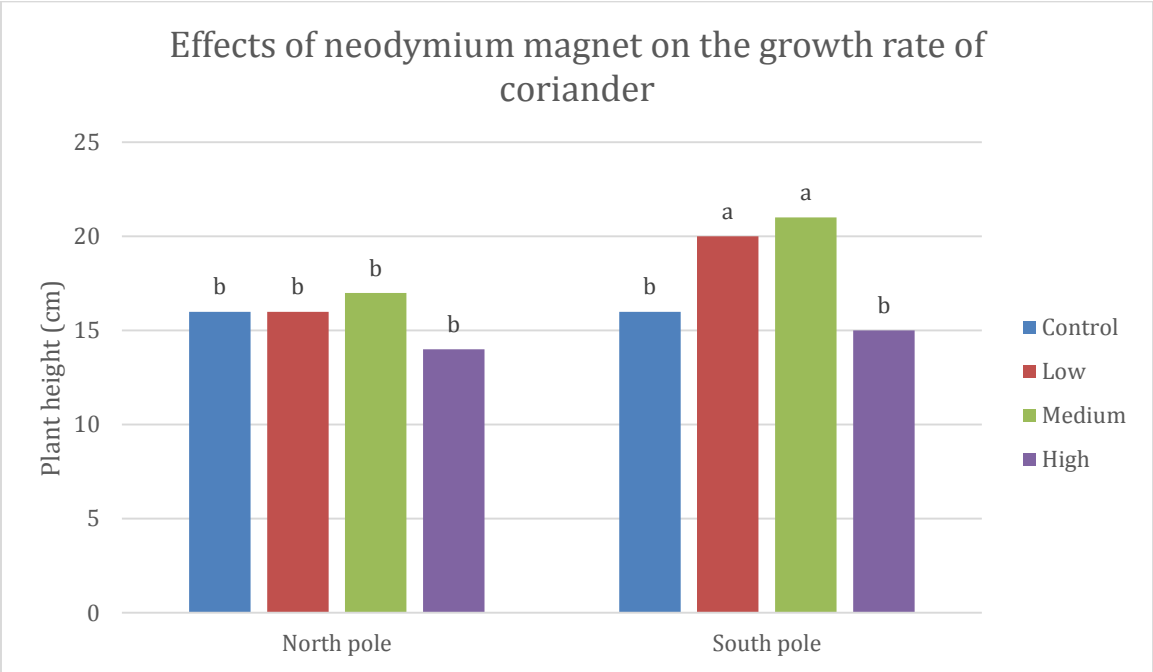
Treatments	Magnet & strengths	Days for germination
0	Control	11.8 b
1	NdFeB (953 μT) (N)	11.5 b
2	NdFeB (1,684 μT) (N)	10.0 b
3	NdFeB (2,504 μT) (N)	11.4 b
4	NdFeB (953 μT) (S)	11.8 b
5	NdFeB (1,684 μT) (S)	8.1 a
6	NdFeB (2,504 μT) (S)	11.3 b

Different letters between treatments differ statistically for p<0.05 according to Dunnett's test

The effects of neodymium magnets were clearly seen in the results of the growth of the plants (Figure 1). These results reflected the plant height at the end of the evaluation period (six weeks). The results in figure 1 show that the magnets placed with the south pole in the upward direction had a more positive effect on plant growth than with the north pole pointing upwards. In the treatments with the south pole pointing upwards, the low and medium strengths magnet had the best growth rate with significant difference among all the other treatments including the control. In both north and south positions, the higher strength magnet had a negative effect on the plant growth. Those plants at the higher magnetic strength had lower growth than the control; however, without significant difference.

Subber *et al*. (2012) concluded that magnetic fields on seeds leads to the acceleration of plant growth, protein biosynthesis and root development. The results obtained in this research proved that the magnetic field certainly influenced the growth of coriander seedlings in a positive way.

Namba *et al*. (1995) noted that the frequency of the field was a more important factor in the germination rate than the polarity. However, this research has revealed that for coriander, both frequency of the field and polarity influenced the germination and growth rate.



Different letters between treatments differ statistically for p<0.05 according to Dunnett's test

Figure1. Effects of neodymium magnets on the growth rate of coriander

Neodymium magnets (NdFeB) are made up of Neodymium, Iron, and Boron, which make these magnets to be the most powerful 'rare-earth' permanent magnet composition known. Ceramic is made up of ferrite are also known as ferrite magnets. This material is made from strontium or barium ferrite. They are less expensive than NdFeB magnets, but still very powerful and resistant to demagnetization.

3.1 The effects of the Ceramic magnets

The ceramic magnets did not have a positive impact in terms of time for the seeds to germinate (Table 4). In none of the treatment there was significant difference with the control, which means that the ceramic magnets did not speed up nor slow down the germination time. However, in the previous experiment, it was seen where neodymium magnets had an impact on the time the seeds take to germinate.

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Table 4. Germination time of coriander seeds subject to ceramic magnetic fields.

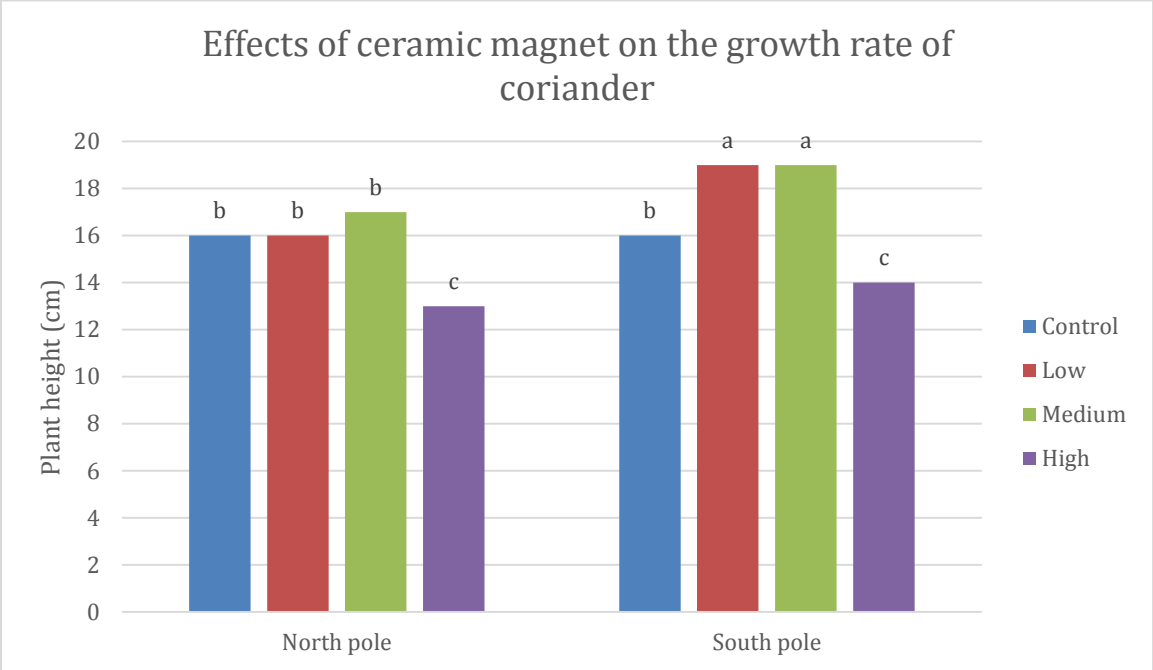
Treatments	Magnet & Strengths	Days for germination
0	Control	11.8 a
1	Ceramic (850 µT) (N)	11.7 a
2	Ceramic (1,506 µT) (N)	11.9 a
3	Ceramic (2,485 µT) (N)	12.0 a
4	Ceramic (850 µT) (S)	11.5 a
5	Ceramic (1,506 µT) (S)	11.1 a
6	Ceramic (2,485 µT) (S)	11.3 a

Different letters between treatments differ statistically for p<0.05 according to Dunnett's test

Despite not having any significant differences between the treatments, numerical values show that the south pole produce better values than the north pole in terms of time the seeds take to germinate.

In terms of the growth rate in the treatment with ceramic magnets, it was clear that the south pole had more positive results (Figure 2). In the case of the south pole, both low and medium size magnets had greater values than the control and the higher strength magnet with significant differences between them.

In the case of the treatments with the north pole, the control along with the low and medium strengths magnetic had higher values than the highest strength magnet with significant difference between them. When all the treatments were compared, the best results proved to be the low and medium strengths magnet with their south pole pointing upwards. These two treatments were significantly superior to all the other treatments. Hence it was clear that the position of the poles played a role in the growth rate of the plants.



Different letters between treatments differ statistically for p<0.05 according to Dunnett's test

Figure 2. Effects of ceramic magnets on the growth rate of coriander.

When the values for both types of magnets were compared, it showed that neodymium magnets had a more positive effect on the plant growth than ceramic.

When both types of magnets were compared, the low and medium strengths neodymium magnets showed the best positive effects on the growth of the cilantro plants. A possible explanation is that the overall strengths of the neodymium magnets that were used were stronger than the ceramic magnets. Magnetic fields accelerate seedling growth, activates protein formation and root development. Since, magnetic fields interact with the ionic current in the embryo cell membrane. Evidence indicates that the Earth's magnetic pull influences seed germination as it acts as an auxin or plant hormone. Studies have shown that magnetic treatment of seed enhances germination by speeding up the formation of protein in the cells, thus, growth is more rapid and robust. Plants react to magnets as it seems that magnetic force pulls apart ions and changes the chemical composition of such things as

salts. Subsequently, plants have a natural response to detect gravity and the effect of magnetism changes the mitochondria in cells and enhance plant metabolism.

The results obtained with the ceramic magnets in the different pole position can be attribute to the composition of the ceramic magnet which is ferrite.

The role of magnetic fields and their influences on functioning of biological organisms are being actively studied and this discipline is called magnetobiology. Magnetobiology is a new synthetic discipline encompassing the principles and techniques of many sciences, from engineering, physics, chemistry, biology and centered on biophysics (Subber *et al*., 2012).

Magnetic fields (MFs) influence the germination, growth, development, and yield of plants. Studies on MFs have shown to modify seed germination and seedling growth and development in a wide-range of plants including field, and industrial crops, such as, cereals, grasses, herbs, medicinal plants, horticultural crops, and trees. This is important since MFs may constitute a non-residual and non-toxic stimulus (Da Silva & Dobranszki, 2015). Magnetic field treatments on seeds leads to the acceleration of plant growth, protein biosynthesis and root development. Also, the strong influence on the fast-initial growth stage of the plants after germination is well known compared with those without a magnetic field influence (Subber *et al*., 2012).

Shine *et al*. (2012) showed that different magnetic fields improved the germination rate of soybean seeds, however, these experiments were done under *in vitro* conditions.

4. CONCLUSION

Neodymium magnet showed positive effect on the germination and growth of coriander. The low and medium strengths magnets with their south poles pointing upwards produced the highest growth rate. Ceramic magnets had no influence on the germinations and didn't have as great an impact on the growth rate as the neodymium magnets. The results revealed that the type of magnetic, the frequency of the magnetic field and the polarity influenced the germination and growth rate of coriander seedlings.

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