

The influence of static strong magnetic field on the germination and growth of garden cress (*Lepidium sativum*, L.).

ABSTRACT

Aims: The aim of the study was to analyze the effect of stable magnetic field produced by a neodymium-iron-boron magnets on the germination and growth of garden cress (*Lepidium sativum* L.) during the entire period of its vegetation.

Methodology: At the bottom of vessels with garden cress seeds (sample tested) magnets with an established direction of the vector of magnetic field were placed. In the first phase the magnets were put with the south pole facing up, and in the second phase the magnets were put with the north pole facing up. The control group consisted the vessels with garden cress seeds under which nonmagnetic cylindrical bars, magnets size, were located. Then, created the optimum conditions for plant growth. Observations were performed during 25 days. Every day the diameter of the growing area were measured and simultaneously the photographic documentation were collected. On adjusted photos a percentage of green was analyzed.

Results: In both experiments *Lepidium sativum* seeds began to sprout on the first day. There were no significant differences in the green of field between magnetized group and control group in first 2 days. The plants cultivated on the magnets with the south pole facing up had the field of growth significantly larger than the control probes on almost all days whereas the plants cultivated on the magnets with the north pole facing up had similar growth area to control except for day 7.

Conclusions: The magnetic field generated by neodymium magnets has no impact on germination of garden cress. However the magnetic field similarly to Earth' magnetic field arouse growth of *Lepidium sativum*.

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Keywords: neodymium-iron-boron magnet, plant growth, germination

1. INTRODUCTION

The first notice of magnetism was in ancient times. In *De Simplicium Medicamentorum Facultatibus* (ca. 200 BC), Galen referred to the use of magnets in therapy. Also Paracelsus (the father of modern medicine; 15th century), recommended magnetotherapy as a form of treatment. At the beginning of the 17th century William Maxwell in *Medicina Magnetica*, wrote that *There is a universal attraction, or what some people call a world-soul, it is life, as fire and ethereal as light itself. All matter is destitute of action, except when this life-force, magnetic force, permeates it* [1]. In the second half of the 19th century, first attempts on impact of magnetic field on plants was published by J. Reinke [2]. Unfortunately negative opinions of his experiments put a stop to further research for dozen of years, until in 1893 Tolomeidis provided conclusions of Reinke, by showing the positive effect of magnetic fields on sprout and plant development. He also discovered the magnetotropism of plants roots.

The development of studies on the effect of magnetism on plants is dates back to the second half of the previous century. These studies typically analysed effect of magnetic fields on the seeds of grains and fruit trees. As a result, a result diminished requirement of oxygen during sprout was observed as well as an increase in the synthesis of proteins, nucleic acids and carbohydrates [3,4]. Sometimes results of these types of experiments were not consistent, mainly because different magnetic fields (static, pulsed) with different intensities (weak, low, strong) and different schedules and plants were used [5 , 6, 7]. What is interesting is that the influence of strong magnetic fields on the growth of medicinal herbs has not yet been tested *Lepidium sativum* Linn. (family: Brassicaceae) is one of the fastest growing, and most edible, annual herbs. It originates from the region of present Ethiopia and western Asia, to the Europe was delivered by Romans, and has been known in Poland since the 15th century [8,9]. Garden cress has a bitter taste and specific scent and as a valuable natural source of vitamins and minerals in Western countries is used as a compound for salads, and has become a popular complimentary medicine.

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Garden cress is commonly used from ages in Ayurveda (an Indian complementary and alternative medicine system), this plant was also recommended in ancient times by Hippocrates, as well as Islamic doctors of medieval era [10]. Its seed extracts seedlings and mature plant has, as well as a wide range of promoting health activities such as hypotensive, antimicrobial, bronchodilator, hypoglycemic and allelopathic, apoptotic, which aid in cancer prevention [11,12].

Cress is recommended as a complimentary drug in the treatment of asthma, coughs with expectoration, poultices for sprains, leprosy, skin diseases, scurvy, cancers, and seminal weakness. [13,14]. It has also been proven that *Lepidium sativum* help in osteoarthritis, most likely due to its anti-inflammatory properties [15,16]. The doses of administered herb should be limited because of its diuretic properties, which could reduce the bioavailability of certain medical drugs [17]. Also seeds and its derivatives are not recommended in early pregnancy – cress seeds were used to carry out abortions in the early stages of fetus development [18]. The knowledge of cress is not complete, as shown by recent discoveries of a new isoflavonoid, 5,6-dimethoxy-2',3'-methylenedioxy-7-C-β-d-glucopyranosylisoflavone isolated from the seeds. This compound, along with two previously known isoflavonoids, has anti-oxidative and hepatoprotective properties [19]. Also two new acylatedflavonol glycosides were isolated from the cress seeds, but their usefulness in pharmacology has not yet been established [20].

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The aim of this study was to evaluate the effect of the stable magnetic field generated by neodymium-iron-boron (NIB) magnets on the germination and growth of garden cress.

2. MATERIAL AND METHODS

2.1 MATERIALS

In the experiment on the seeds of garden cress (Poland) and permanent Nd₂Fe₁₄B (N38), round magnets (33x10 mm) were used. The magnets were factory made, coated with Ni-Cu-Ni layer, their magnetic field vector was axial, with remanence (Br): 1.21 – 1.25 T (12,1-12,5 kGs), coercivity (bHc): min. 11,3 kOe, coercivity (jHc): min. 12,0 kOe and maximum energy density (BH) max.: 286-302 kJ/m³ or 36-38 MgsOe.

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2.2 METHODS

A serial of identical round vitrioceramic sprouters was prepared as follows. A magnet with an established direction of the vector of magnetic field was placed at the bottom of every vessel. In the first phase (I), the magnets were put with the south pole facing up, and in the second phase (II) the magnets were put with the north pole facing up. Cylindrical bars made of aluminum were located in the control vessels identical in dimension. To avoid any influence of compounds from the magnets or aluminium bars all of them were firmly closed in plastic ziploc bags. The bars were covered with strictly weighted (Sartorius MD1; Germany) 5.43g of lignin and 5g of garden cress seeds were smoothly sowed in each vessel. At the beginning, 40 ml of tap water was added to all sprouters. Three vessels with magnets and three control vessels were put in the dark room under a fluorescent lamp of 120 cm in length (T8, Mesko, Poland). The lamp was switched on 12 hours per day (8 am – 8 pm), using an electronic controller (Dahl, Germany). All seeds and later plants had the same access to the light. The temperature in the room was controlled using a thermometer (Sunbean (USA)). During the light phase in the location of sprouters, the temperature was between 25 - 26 centigrade, and in the dark phase between 20 - 21 centigrade. Every day, at the same time, 15 ml of tap water was delivered to each sprouter. Also at the same time, once per day every vessel was photographed using a tripod and digital camera (Olympus, Japan), and when the cress sprouted the diameter of visible growth was measured using a digital caliper (PowerfixProfi, UK). Minimal, maximal and

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No height data was recorded

optically mean diameters were measured to 0.1 cm precision (Fig. 1). Measurements stopped being taken when vegetation ceased.



Fig. 1 Measurements of garden cress' growth

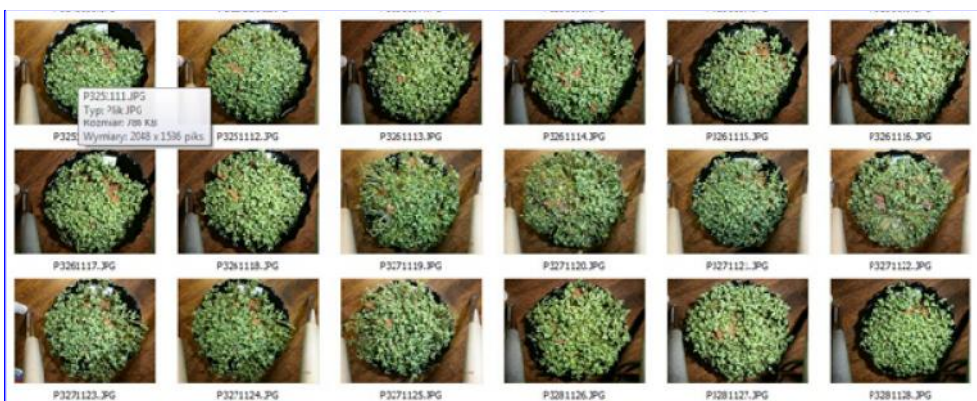


Fig. 2. Examples of photos

The photos were adjusted with the dimension of the vessels as a benchmark, using Microsoft Office 2010 (fig. 2). The percentage of green in the pictures was obtained using Ink Calculator 5.0.1.35 (freeware; by D. Najgiebauer). The experiment was then repeated.

2.3 STATISTICS

The statistical analysis was performed in Microsoft Office Excel 2010 (Microsoft, USA) and Statistica 8 (StatSoftPolska). The results were presented using descriptive statistic functions, such as arithmetic mean, median, minimum and maximum values and standard deviation. Differences between groups were tested for statistical significance by Student's t-test. $P \leq .05$ was considered significant.

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3. RESULTS AND DISCUSSION

The development of neodymium magnets provide the opportunity to explore the influence of strong magnetic fields on plant development with new quality.

In both phases of this study, seeds of *Lepidium sativum* began to sprout on the first day. There were no significant differences in the green of field (pictures) between magnetized group and control group in first 2 days. Observations were, therefore, performed once per day. It would be not a sufficient to show a delicate distinct in this matter. There are a lot of papers that strong magnetic field boost sprout [21, 22 ,23]. However the theory concerning the of lack of effect of magnetic field on the germination of *Lepidium sativum* confirm no differences in green on the pictures taken in the first three days of the growth between studied and control probes.

After 3 days, the field of growth was visible, differentiated and measureable. In the case of the plants cultivated on the magnets with the south pole facing up, the area of growth was significantly larger than in control probes on almost all days (except day 6) (Fig. 3 I). Adversely, the growth of the plants cultivated on the magnets with the north pole facing up was similar to the growth in control probes except for day 7 (Fig. 3 II). This one-day exception means that the diameter of growth in the studied magnetized group was higher than in the control group. On day eight, the field of growth successively diminished. On the 11th - 13th day plants become weak, and must revise.

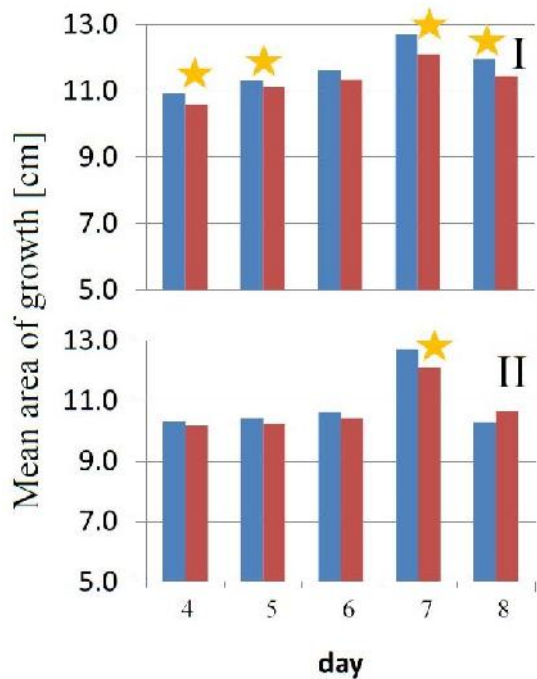


Figure 3. Mean diameter of growth area in the magnetic field (blue bars) – I. magnets with south pole facing up, and II – magnets with north pole facing up. Red bars – control probes. Asterisks indicated statistically significant differences.

Analysis of the mean percentage of green on the pictures of cultivations confirm better growth of plants on south pole of magnets (Fig. 4I), however observed differences were not statistically significant. The mean green of probes cultivated on north pole of magnets was very similar to that present in the control group (Fig. 4 II).

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Comment [s18]: How it was known as strong? What is the reference for strenght being low or high/weak or strong?

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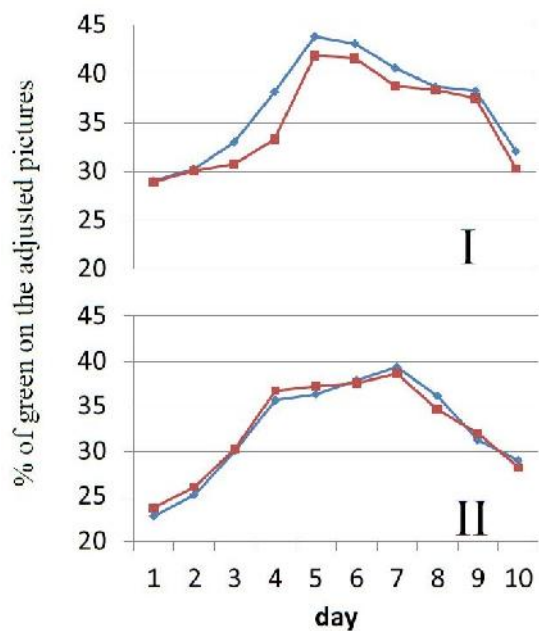


Figure 4. Mean percentage of green on the unified pictures of the cultivated probes. I – phase I magnets with south pole facing up, and II phase – magnets with north pole facing up. Blueline – magnetized probes, red line – controls.

Magnetotropism of plants has been explored since the sixties. The oriented growth of plants in magnetic fields was observed,[24] as well as the root development toward the regions of the decreasing field strength in the inhomogeneous magnetic field [25]. In this study the cultivation on the north pole also showed better growth, however in this case there were no significant differences when compared to the control group(s). The same conclusion was drawn based on the analysis of green in the pictures documenting growth. These observations are consistent with the recent study of Poinapen et al, however in older studies by Sperber et al magnets enhanced growth despite their orientation [26 ,27].

The differences in growth between cultivation on north and south pole of strong magnets could be related to the orientation of magnets in regard to the Earth's magnetic field. The south pole on the top oriented magnets had synergistic effect with magnetic field of the planet whereas the North pole on the top oriented magnets had an adverse effect on the magnetic field of the planet (the experiments were done on the north hemisphere, fig. 5). However, in these experiments magnets generated strong magnetic field over 1 tesla (T), whereas Earth's magnetic field in Europe is around 40-50 mT.

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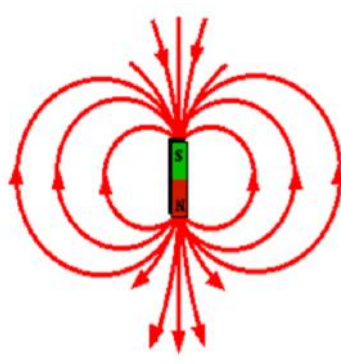
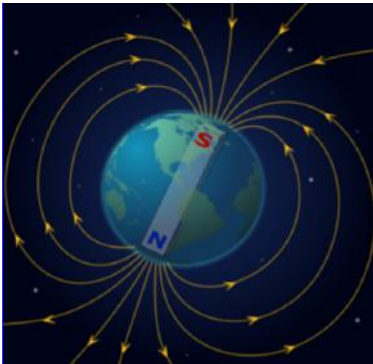


Fig 5. Earth's magnetic field and magnetic field around permanent magnets.

The enhancement of Earth's magnetic field by magnets could be responsible for a bigger area of growth as the plant roots developed on the sides of magnets toward to diminished magnetic field. The other explanation is based on the action of Lorentz force in magnetic or electromagnetic fields. Lorentz force influences ions as well dipole molecules as water [28]. Lorentz force modifies the location of these molecules and ions between biological compartments, inside subsequent compartments and in biological membranes [29]. All of this results in changes in transmembrane potentials and Hall effects. These changes would be beneficial, but also could result in the destruction of delicate molecular balance [30]. Another interesting perspective for future research on the effects of magnetic fields on plants is a hypothesis that similarly to some animal species plants also have magnetoreceptors [31].

In summary, the effect of a natural, geomagnetic field, as well as artificial magnetic fields, on plants are not yet fully understood. This study showed that the orientation of permanent magnets has significance on their growth, but not on sprout.

4. CONCLUSION

4.1 Strong magnetic field generated by neodymium magnets has no impact on germination of garden cress.

4.2 Magnetic field generated by neodymium magnets orientated similarly to Earth's magnetic field stimulated growth of garden cress.

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Comment [s23]: Delete No need of this figure, actual value would be if earth's magnetic flux was measured at the experiment site, how it was influenced by magnetic bars placed with either north or south pole upwards.

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Comment [s27]: Could be the influence plant population by itself and nutrient deficit thereof.

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