American Journal of Experimental Agriculture
7(4): 251-256, 2015, Article no.AJEA.2015.127
ISSN: 2231-0606

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The Influence of Strong Static Magnetic Field on the Germination and Growth of Garden Cress (*Lepidium sativum* L.)

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Authors' contributions

This work was carried out in collaboration between all authors. Authors FJK and BKK designed the study, wrote the protocol, performed study and statistical analysis and wrote the first draft of the manuscript. Author PJT supervised all stages of the study and managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJEA/2015/15862
Editor(s):
(1) Vladimir K. Mukhomorov, Agrophysical Institute, 14 Grazhdanskiy Ave., St-Petersburg, 195220, Russia.
(2) Daniele De Wrachien, State University of Milan, Italy.
Reviewers:
(1) Anonymous, Bulgaria.
(2) Sadar Uddin Siddiqui, Plant Genetic Resources Program, National Agricultural Research Centre, Pakistan.
(3) Anonymous, Malaysia.
(4) Tarlochan Singh Mahajan, Physics Department, Khalsa College, Patiala (Pb), India.
Complete Peer review History: http://www.sciencedomain.org/review-history.php?iid=918&id=2&aid=8363

Short Research Article

Received 22nd December 2014
Accepted 9th February 2015
Published 7th March 2015

ABSTRACT

Aims: The aim of the study was to analyze the effect of static magnetic field generated by a neodymium-iron-boron magnets on the growth of garden cress (*Lepidium sativum* L).

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 of garden cress cultivated on nonmagnetic cylindrical bars of magnets size. Every day the diameter of the growing area were measured and simultaneously the photographic documentation was collected. On adjusted photos a percentage of green was analyzed.

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Results: In both experiments *Lepidium sativum* seeds began to sprout on the first day. After three 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.
Conclusion: Magnetic field generated by neodymium magnets orientated similarly to Earth` magnetic field stimulated growth of garden cress.

Keywords: Neodymium-iron-boron magnet; plant growth; germination.

1. INTRODUCTION

In the second half of the 19^{th} century, first attempts on impact of magnetic field on plants was published by J. Reinke and by affirmed by Tolomeidis [1]. They showed the positive effect of magnetic fields on sprout and plant development. Further studies typically analyzed effect of magnetic fields on the seeds of grains and fruit trees. As a result, diminished requirement of oxygen during sprout was observed as well as an increase in the synthesis of proteins, nucleic acids and carbohydrates [2]. Results of these experiments are not consistent, mainly because different magnetic fields used (static vs. pulsed) with different intensities (weak, low, strong) and different schedules as well plants were used [3-5]. The influence of strong magnetic fields on the growth of medicinal herbs has not been analyzed yet. *Lepidium sativum* (garden cress) is one of the fastest growing, and most edible, annual herbs. Garden cress due to a bitter taste and specific scent is used as popular a compound for salads. What is more this herb is valuable natural source of vitamins and minerals and has anti-inflammatory, diuretic, anti-oxidative and hepatoprotective properties [6-9]. The aim of this study was to evaluate the effect of the stable magnetic field generated by neodymium-iron-boron (NIB) magnets on the growth of garden cress.

2. MATERIALS AND METHODS

2.1 Materials

In the experiment the seeds of garden cress (Polan, Poland) and permanent $Nd_2Fe_{14}B$ (N38), disc magnets (33 x 10 mm) (Xinxin, Poland) were used. The magnets were coated with Ni-Cu-Ni layer, their magnetic field vector was axial, with remanence (Br): 1.21 – 1.25 T (12,1-12,5 kG), coercivity (bHc): min. 11,3 kOe, coercivity (jHc): min. 12,0 kOe and maximum energy density (BH) max.: 286-302 kJ/m^3 or 36-38 MgsOe.

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 (paramagnetic element; magnetic susceptibility 2.2) 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) 5.43 g of lignin and 5 g 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 25±1 centigrade, and in the dark phase 21±1 centigrade. Every day, at the same time, 15 ml of tap water (collected in the container at the beginning of experiment) 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 visually mean diameters were measured to 0.1 cm precision (Fig. 1). Measurements were stopped when vegetation ceased.

The photos were adjusted with the dimension of the vessels as a benchmark, using Microsoft

Office 2010. The percentage of green in the pictures was obtained using Ink Calculator 5.0.1.35 (freeware; by D. Najgiebauer). The experiment was duplicated.

2.3 Statistics

The statistical analysis was performed in Microsoft Office Excel 2010 (Microsoft, USA). 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.

Fig. 1. Measurements of garden cress` growth

3. RESULTS AND DISCUSSION

The neodymium magnets give the opportunity to explore the influence of strong magnetic fields (over 1 T) on plant development. These magnets despite their relatively small dimensions generated magnetic field thousands more intense than Earth`s magnetic field (in Europe 40-50 µT). In both phases of this study, seeds of *Lepidium sativum* began to sprout on the first day and no differences were observed in this matter between studied and control groups. There were also no significant differences in the green of field (pictures) between magnetized groups and control groups within first 2 days. There are a lot of papers showing that strong magnetic field boost sprout [10-12]. Observations in this study were performed once per day. It would be not sufficient to show a delicate distinct differences in germination. However lack of effect of magnetic field on the germination of *Lepidium sativum* are confirmed by 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. 2 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. 2 II). This day the mean diameter of growth in the studied magnetized group was higher than in the control group. On day eight and later, the field of growth in all groups successively diminished. On the 11th - 13th day plants become weak, and overgrown with mold.

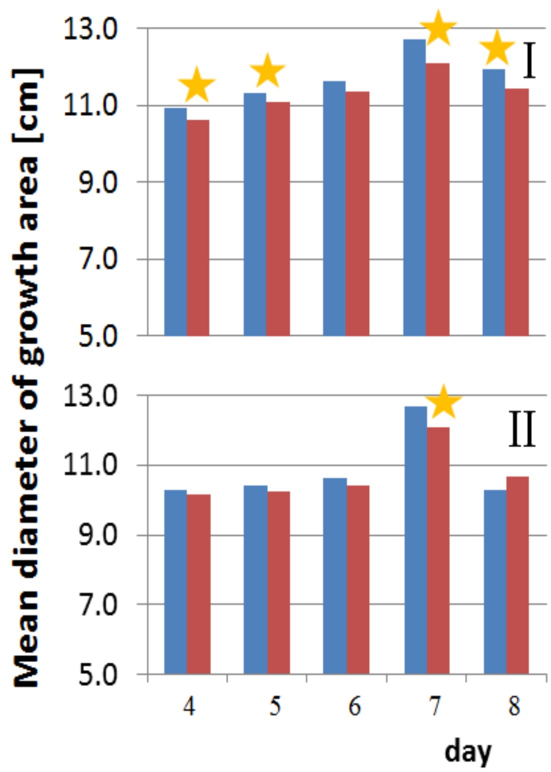

Fig. 2. Mean diameter of growth area in the magnetic field (blue bars) – I. magnets with south pole facing up, and II – magnets with north pole facing up. Red bars – control probes. Asterisks indicated statistically significant differences

Analysis of the mean percentage of green on the pictures of cultivations confirm better growth of plants on south pole of magnets (Fig. 3 I), however observed differences were not statistically significant. The mean green of probes cultivated on north pole of magnets was very similar to the control group (Fig. 3 II).

Magnetotropism of plants has been explored since the sixties. The oriented growth of plants in magnetic fields was observed, as well as the root development toward the regions of the decreasing field strength of magnetic field [13]. In older studies by Sperber et al. [14] magnets enhanced growth despite their orientation, but the recent study of Poinapen et al. [15], similarly to the present study showed better growth of the plants cultivated on the north pole. 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). 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 [13]. 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 [16]. Lorentz force modifies the location of these molecules and ions between biological compartments, inside subsequent compartments and in biological membranes [17]. All of this, results in changes intransmembrane potentials and Hall effects. These changes would be beneficial, but also could result in the destruction of delicate molecular balance [18]. 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 [19].

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 neodymium magnets has significance on garden cress growth, but not on sprout.

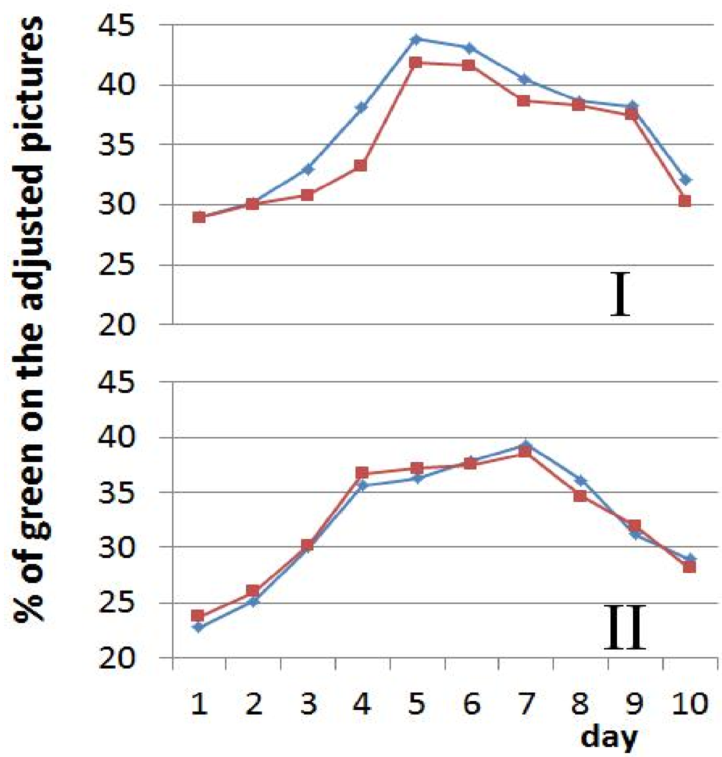

Fig. 3. Mean percentage of green on the unified pictures of the cultivated probes. I – phase I: magnets with south pole facing up, and II – II phase: magnets with north pole facing up. Blueline – magnetized probes, red line – controls

4. CONCLUSION

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

ACKNOWLEDGEMENTS

Authors would like to thank Mrs Elżbieta Opozda-Zuchmańska (Witkowski High School, Cracow, Poland) for kind scientific support and valuable comments.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=918&id=2&aid=8363