INTRODUCTION

During the current years, the agricultural efforts shift to an effective and environmentally clean technology based on physical treatment of the plants or their seeds to increase the seedling vigour and crop production. The previous studies showed that exposure to suitable magnetic fields is one of the affordable physical treatments to enhance the growth of plants (Radhakrishnan, 2019; Vashisth & Joshi, 2017). The impacts of the magnetic field on biological systems, especially on the growth of plants and germination of seeds, have been attracted to the attention of scientists in this field. Magnetic fields can affect germination rate, seed vigour, seedling growth, and yield (Maheshwari & Grewal, 2009; Mroczek-Zdyrska, Tryniecki, Kornarzyński, Pietruszewski, & Gagoś, 2016; Nyakane, Markus, & Sedibe, 2019).

Many factors affect plant growth and development, such as exposure to electromagnetic radiation (Alattar, Alwasife, & Radwan, 2020) and magnetic fields (Podleśna, Bojarszczuk, & Podleśny, 2019). Many studies have extensively studied the direct exposure to plants or their seeds to magnetic fields from the past years. However, little has interested in the impact of magnetized water on the growth characteristics of plants. Passing water through a magnetic field resulted in producing magnetized water (Higashitani, Kage, Katamura, Imai, & Hatade, 1993). The previous studies revealed that a low magnetic field could alter the water to be magnetized (Ji, Xie, & Liu, 2007). As a result of magnetization, water properties, including physical, chemical, physicochemical, and biophysical properties, change such as salt solution capacity, density, viscosity, freezing and boiling points, surface tension, electrical conductivity,

ARTICLE INFO

Keywords:
Chilli pepper (Capsicum annuum) plants
Magnetic fields
Magnetized water
Neodymium magnets

Article History:
Received: January 3, 2021
Accepted: April 26, 2021

* Corresponding author:
E-mail: ernp2030@gmail.com

ABSTRACT

The present study aims to identify the impact of magnetized water on the growth characteristics of chilli pepper (Capsicum annuum) plants. A total of 80 chilli seeds were separated into four groups: the first group was watered with non-magnetized water, while the three groups were dampened with water magnetized using 3, 6, and 9 neodymium magnets (NdFeB), respectively. The findings revealed that magnetized water caused changes in the study parameters. Although the plants watered with magnetized water were taller than the plants watered with non-magnetized water, there were no significant differences between the four groups (p = 0.224). The results revealed that the stem thickness of chilli peppers is pretty affected by the magnetized water. There was no significant difference between the four treatments (p = 0.218). The current study found that the number of leaves is significantly influenced by watering with magnetized water (p = 0.015). The leaves of chilli peppers dampened with water treated with six magnets (74.50 ± 13.57) were the highest, and those saturated with non-magnetized were the lowest in number (60.00 ± 6.09) among four groups. The influence of magnetized water relies on the number of magnets utilized for magnetizing water.

Growth Characteristics of Chilli Pepper (Capsicum annuum) under the Effect of Magnetizing Water with Neodymium Magnets (NdFeB)
Etimad Alattar1), Khitam Elwasife2) and Eqbal Radwan1)*
1) Department of Biology, Faculty of Science, Islamic University of Gaza, Gaza Strip, Palestine
2) Department of Physics, Faculty of Science, Islamic University of Gaza, Gaza Strip, Palestine
hydrogen bond formation, pH, water molecule size, and dielectric constant (Amiri & Dadkhah, 2006; Chang & Weng, 2006; Ji, Xie, & Liu, 2007).

Most of the previous studies have widely discussed the response of living systems to low, moderate, and vigorous magnetic fields (Pazur, Schimek, & Galland, 2007; Saunders, 2005; Zablotskii, Polyakova, Lunov, & Dejneka, 2016). Despite many studies concerning the influence of direct or indirect exposure to magnetic fields on living materials, the exact impact of magnetic fields is still under examination (Chibowski & Szcześ, 2018). According to the literature review, exposure to magnetic fields is different as magnetic fields affect (inhibitory or activating effect) or no significant impact on the biological materials. The other magnetic field products on exposed plants produce several factors such as the intensity of the magnetic field, polarity, type of magnets, flowing water, exposure time, type of water sample, and the magnetic field pathway duration (Podsiadło & Skorupa, 2017). Moreover, plant species is considered one of the main factors affected by a magnetic field. The magnetic field should be identified individually on desired plants before applying on a larger scale (Surendran, Sandeep, & Joseph, 2016; Zaidi, Sohaili, Muda, & Sillanpää, 2014).

Magnetized water has a beneficial impact on germination rates of seeds (Matwijczuk, Kornarzyński, & Pietruszewski, 2012; Patil, 2014); percentages of emergence (Podleśny, Pietruszewski, & Podleśna, 2004), root growth (Turker, Temirci, Battal, & Erez, 2007), moving of nutrients from fertilizers to soil (Hozayn & Qados, 2010), plant yield (Maheshwari & Grewal, 2009; Patil, 2014), as well as the water-holding capacity of the soil (Al-Khazan, Abdullatif, & Al-Assaf, 2011). In addition, it was found that magnetized water helps plants overcome the harmful effect of water deficit (Selim & El-Nady, 2011). Moreover, deploying magnetically treated water reduces deep percolation and increases soil moisture, resulting in shorter irrigation cycles (Surendran, Sandeep, & Joseph, 2016).

To date, studies on using magnetized water in the watering of plants, especially chilli pepper, are still rare. So, the current study aimed to identify the influence of magnetized water on the growth of chilli plants grown in the Gaza Strip, Palestine.
that opposite poles face each other and generate the required magnetic field between the two poles, allowing the magnetic field to treat water (Pazur, Schimek, & Galland, 2007) efficiently. At a distance of 100 mm, the magnets were placed at the end closest to the plant. Fig. 2 depicts the installation of the magnets inside the pipeline system. After all, the pipe was ready, so they were put in the field with the same containers to irrigating the plants.

**Field Experiment**

This experiment used 80 chilli pepper seeds from a local farm in East Gaza. Corn seeds having healthy and uniform-sized without insect damage, visible defect, and malformation were chosen and divided into four parts in a randomized complete block design. The chilli pepper seeds were sterilized with a 1% sodium hypochlorite and then washed with sterile distilled water. According to agricultural specialist guidelines, the chilli pepper seeds were then correctly placed in the soil field. The tested seeds were selected due to the lack of papers that study the response of chilli pepper to magnetized water with a different magnetic flux density. Furthermore, they grow during the study experiment. Also, it is easy to transfer chilli pepper plants to the laboratory and carried out the desired tests.

**Fig. 1.** Block diagram of the experimental setup

**Fig. 2.** Magnetizing water system: (A) non-magnetized water; (B), (C) and (D) Magnetized water with 3, 6, and 9 magnets, respectively
All of the remaining variables were maintained constant. Also, to minimize unpredictable variables that affect the growth of chili pepper plants, a consistent watering period was held, and the treatment times were correctly planned. During the experiment, chili peppers were treated with 13-13-13 NPK fertilizer, which was added according to the Haifa NutriNetTM company recommendation (Nutritional recommendations for pepper, 2019). Table 1 illustrates the nutrient content of fertilizer. Throughout the present study, the plants were also treated with Roger pesticides, where all chili peppers got the same amount simultaneously.

At the end of the study, shoot length, stem thickness, and the number of leaves/plants were counted. The thickness and length of plants were measured using a capillary and ruler, respectively. These variables were selected because they show the growth of plants under the effect of the tested environment. The investigated parameters are good indicators for interpreting the changes caused by directly or indirectly exposure to magnetized water.

**Statistical Analysis**

The Statistical Package for the Social Sciences (SPSS) software, version 22, was used to analyze the obtained data. The data were presented as mean ± standard deviation. The comparisons of means between four groups were carried out by one-way analysis of variance (ANOVA). A p-value <0.05 was considered a statistically significant difference for all the statistical tests.

**RESULTS AND DISCUSSION**

The study assessed the impact of magnetized water from the growth characteristics of chili pepper plants. The findings showed that magnetized water changed the growth of treated plants during the research duration. The overall results can be seen in Table 2.

**Effect of Magnetized Water on Shoot Length**

The findings showed that the length of treated plants was found different depend on the type of irrigation water. Every seven days, the shoot length of chili peppers was measured in all groups until the last day of the study. Fig. 3 compares the mean shoot length of plants grown in the fourth group.

On day 43, it was noticed that the magnetized water had a similar trend respecting plant lengths. The results revealed that the magnetized water fairly influences the shoot length of chili peppers. Among four treatments, plants in the M6 group recorded the higher plant length (73.83 ± 11.30 cm), and the lowest was found in the control group (59.80 ± 5.93 cm). Although the plants watered with magnetized water were taller than the plants watered with non-magnetized water, there were no significant differences between the four groups (p = 0.224).

This finding was following the discovery mentioned in the study of Alattar & Radwan (2020). They conducted a study to identify the impact of magnetized water on the growth of pepper (Capsicum annuum). They selected pepper plants and separated them into four groups. The first group was given non-magnetized water, and the rest groups were given magnetized water (magnetized with at 3, 6 and 9 magnets). They found that magnetized water does not affect the length of treated plants. On the contrary, these results disagree with the results reported in other studies, which saw an inhibition or a stimulatory impact of
magnetized water on the shoot length of plants in treated groups. For example, Ahamed, Elzaawely, & Bayoumi (2013) carried out a study to investigate the impact of the magnetic field on the growth of sweet pepper (*Capsicum annuum*). They found that the growth characteristics were increased in the treated plants when compared to control plants. They revealed that the magnetic field is a suitable method for treating the seeds that promote their growth. In addition, the similar stimulatory effect of magnetized water on shoot length was obtained on different crops such as barley (Martinez, Carbonell, & Amaya, 2000), cowpea (Tahir & Karim, 2010), soybean (Radhakrishnan & Ranjitha Kumari, 2012; Shine, Guruprasad, & Anand, 2011), garden pea (Iqbal, Muhammad, Zia-ul-Haq, Jamil, & Raza Ahmad, 2012), tomato (Feizi et al., 2012), brinjal (Sadeghipour & Aghaei, 2013), cucumber (Shahin, Mashhour, & Abd-Elhady, 2016), chickpea (El-Zawily et al., 2019), corn (Alattar, Elwasife, Radwan, & Abuassi, 2019) and pepper (Ahamed, Elzaawely, & Bayoumi, 2013). They found that magnetized water increased the shoot length of treated plants.

In contrast, different results have been reported in wheat (*Triticum aestivum*) cultivars: Sakha 93, Masr 1 (Almaghrabi & Elbeshehy, 2012), and NR-234 (Ijaz, Jatoi, Ahmad, Masood, & Siddiqui, 2012). They showed that the plants watered with magnetized water had a lower shoot length than that of control. Moreover, some experiments found a negative impact of magnetically treated water on plant lengths, such as Ijaz, Jatoi, Ahmad, Masood, & Siddiqui (2012). They carried out a study to assess the influence of magnetized seed and magnetized water on wheat seeds. They showed that the length of treated plants was lower than those watered with non-magnetized water.

The inhibitory or stimulatory impact of magnetized water on the length of pepper plants may be due to treated water on protein formation, biochemical process, and activities of enzymes. It was proposed that the magnetic field stimulates root development and plant growth. These modifications may be because the magnetic field interacts with ionic fluxes through the cell membrane, which induces variations in osmotic pressure, ion concentrations, and water uptake (Eladjadjiyan, 2002; Atak, Çelik, Alikamanoğlu, & Rzakoulieva, 2007). The magnetic field also influences the soil/water interface. It causes the destabilization of gas bubbles, therefore upsetting the balance of ions between the shell of absorbed negative ions and counter ions (Hilal & Hilal, 2000).

### Table 2. Effect of magnetized water on the growth of chilli pepper plants

| Irrigation Treatment | Shoot Length (cm)   | Stem Thickness (cm) | Number of leaves |
|----------------------|---------------------|---------------------|-----------------|
| ANOVA                | NS                  | NS                  | *               |
| **Multiple range test Tukey** |                     |                     |                 |
| Control              | 63.00 ± 5.93 a      | 1.82 ± 0.22 a       | 60.00 ± 6.09 c  |
| M3                   | 69.83 ± 8.58 a      | 1.90 ± 0.25 a       | 74.16 ± 3.85 a  |
| M6                   | 73.83 ± 11.30 a     | 1.78 ± 0.22 a       | 74.50 ± 13.57 a |
| M9                   | 71.00 ± 3.39 a      | 2.10 ± 0.31 a       | 73.00 ± 3.39 a  |

Remarks: NS = Not significant, * significant at p < 0.05. Means followed by the same letter within the same column were not significantly different (p > 0.05), according to Tukey’s least significant difference test. Control: non-magnetized tap water; M3, M6, and M9 water treated with 3, 6 and 9 magnets, respectively.
Effect of Magnetized Water on Stem Diameter

This study showed that stem thickness changed when watering chilli peppers with magnetized water compared with plants in the non-magnetized group. There is an increase in the stem diameter of plants watered with magnetized water compared to other control counterparts (Fig. 4).

At the end of the experiment, using nine magnets for magnetizing water obtained the highest increase in stem diameter (2.10 ± 0.31 cm). Using six magnets received the lowest (1.78 ± 0.22 cm) compared with plants in the rest groups. Analysis of the obtained results revealed no significant difference among the four treatments (p = 0.218).

A similar result showed different plants such as pear plants (Osman, Abd El-Latif, Hussien, & Sherif, 2014). The study found that the stem diameter did not change when watering pear plants with magnetized water. In contrast, different results obtained on other crops such as corn (Alattar, Elwasife, Radwan, & Abuassi, 2019), mustard plants (Jogi, Dharmale, Dudhare, & Aware, 2015), tomatoes (Yusuf & Ogunlela, 2015; 2017). They showed that watering plants with magnetized water positively affected stem diameter. Plants in magnetized water showed a significantly increased diameter compared to plants that watered with non-magnetized water.

Effect of Magnetized Water on the Number of Leaves/Plant

The current study revealed that leaves number is significantly affected by watered with magnetized water (p = 0.015). The leaves of chilli peppers plants watered with magnetized water were more in number when compared to plants watered with non-magnetized water (Fig. 5). At the end of the study, the leaves of chilli peppers moistened with water treated with six magnets (74.50 ± 13.57) were the highest, and those watered with non-magnetized were the lowest in number (60.00 ± 6.09) among four groups (Table 2).
Fig. 4. Mean stem diameter of chilli pepper plants through the study period.

Fig. 5. Mean of number of chilli pepper leaves during the study period.
These results are in harmony with that obtained in other plants such as strawberry (Eşİtken, 2003), pear (Osman, Abd El-Latif, Hussien, & Sherif, 2014), and corn (Alattar, Elwasife, Radwan, & Abuassi, 2019). They found that the number of leaves/plants was influenced by irrigation with magnetized water. Plants in magnetized water showed an increase in the number of leaves per plant compared to plants watered with non-magnetized water. El-Gizawy, Ragab, Helal, El-Satar, & Osman (2016) found that the treated potato plants with magnetic fields resulted in many leaves/plants. The results also follow the obtained results in the study of Marks & Szecowka (2010) on potato and Ahamed, Elzaawely, & Bayoumi (2013) on sweet pepper. They found that magnetizing seeds produced plants with a higher number of leaves when compared to plants derived from non-magnetizing seeds. Also, Surendran, Sandeep, & Joseph (2016) found that magnetized water increased the number of leaves compared to control plants. The changes in chemical and physical characteristics of water after magnetizing it may accelerate the biological activity of treated plants and affect plants growth, including the number of leaves per plant. The improvement of vegetative variables, including the number of leaves in plants watered with magnetized water due to a rise in photosynthetic pigment concentrations (i.e. chlorophylls and carotenoids) and protein biosynthesis, activations of hormones and enzymes, and enhancement in the transportation and mobilization of nutrients. The magnetic can cause changes in the transport characteristics of membranes, which are essential in controlling the assimilation of nutrients required for the cell operation. The last changes provided a significant amount of assimilates needed for vegetative growth and thus increased the total number of leaves in treated plants (Dhawi & Al-Khayri, 2009; Leelapriya, Dhilip, & Sanker Narayan, 2003; Maheshwari & Grewal, 2009; Radhakrishnan & Ranjitha Kumari, 2012; Surendran, Sandeep, & Joseph, 2016).

CONCLUSION

The present study tried to identify the impact of magnetized water on the growth of chilli pepper plants. The results showed that the magnetized water caused changes in some growth characteristics of chilli pepper plants. Watering chilli peppers with magnetized water significantly affects the growth parameters, such as the number of leaves. The leaves of plants watered with magnetized water were more in number than plants treated with non-magnetized water. Although the plants watered with magnetized water were taller and thicker than those dampened with regular tap water, there were no significant differences between the four groups. The influence of magnetized water is determined by the number of magnets used in the magnetization water. Therefore watering with magnetized water can be used as a safe method to improve some growth characteristics of the exposed plant. This research highly recommends conducting more studies on other commercial crops and investigating magnetised water impact on their growth.

ACKNOWLEDGEMENT

The authors are grateful to the Department of Biology and Physics at the Islamic University of Gaza for their useful help in conducting the present study.

REFERENCES

Ahamed, M. E. M., Elzaawely, A. A., & Bayoumi, Y. A. (2013). Effect of magnetic field on seed germination, growth and yield of sweet pepper (Capsicum annuum L.). Asian Journal of Crop Science, 5(3), 286–294. https://doi.org/10.3923/ajcs.2013.286.294

Aladjadjiyan, A. (2002). Study of the influence of magnetic field on some biological characteristics of Zea mais. Journal of Central European Agriculture, 3(2), 89–94. Retrieved from https://core.ac.uk/download/pdf/14389409.pdf

Alattar, E., & Radwan, E. (2020). Investigation of the effects of radio frequency water treatment on some characteristics of growth in pepper (Capsicum annuum) plants. Advances in Bioscience and Biotechnology, 11(02), 22–48. https://doi.org/10.4236/abb.2020.112003

Alattar, E., Alwasife, K., & Radwan, E. (2020). Effects of treated water with neodymium magnets (NdFeB) on growth characteristics of pepper (Capsicum annuum). AIMS Biophysics, 7(4), 267–290. https://doi.org/10.3934/BIOPHY.2020021

Alattar, E., Elwasife, K. Y., Radwan, E. S., & Abuassi, W. A. (2019). Influence of magnetized water on the growth of corn (Zea mays) seedlings. Romanian Journal of Biophysics, 29(2), 1–12. Retrieved
Ji, A.-C., Xie, X. C., & Liu, W. M. (2007). Quantum magnetic dynamics of polarized light in arrays of microcavities. Physical Review Letters, 99(18), 183602. https://doi.org/10.1103/PhysRevLett.99.183602

Jogi, P. D., Dharmale, R. D., Dudhare, M. S., & Aware, A. A. (2015). Magnetic water: A plant growth stimulator improve mustard (Brassica nigra L.) crop production. Asian Journal of Bio Science, 10(2), 183–185. https://doi.org/10.15740/has/ajbs/10.2/183-185

Leelapriya, T., Dhilip, K. S., & Sanker Narayan, P. V. (2003). Effect of weak sinusoidal magnetic field on germination and yield of cotton (Gossypium spp.). Electromagnetic Biology and Medicine, 22(2–3), 117–125. https://doi.org/10.1081/JBC-120024621

Maheshwari, B. L., & Grewal, H. S. (2009). Magnetic treatment of irrigation water: Its effects on vegetable crop yield and water productivity. Agricultural Water Management, 96(8), 1229–1236. https://doi.org/10.1016/j.agwat.2009.03.016

Marks, N., & Szecowka, P. S. (2010). Impact of variable magnetic field stimulation on growth of aboveground parts of potato plants. International Agrophysics, 24(2), 165–170. Retrieved from http://www.international-agrophysics.org/Impact-of-variable-magnetic-field-stimulation-on-growth-of-aboveground-parts-of-potato,106367,0,2.html

Martinez, E., Carbonell, M. V., & Amaya, J. M. (2000). A static magnetic field of 125 mT stimulates the initial growth stages of barley (Hordeum vulgare L.). Electro- and Magnetobiology, 19(3), 271–277. https://doi.org/10.1081/JBC-100102118

Matwijczuk, A., Kornarzyński, K., & Pietruszewski, S. (2012). Effect of magnetic field on seed germination and seedling growth of sunflower. International Agrophysics, 26(3), 271–278. https://doi.org/10.2478/v10247-012-0039-1

Mroczek-Zdyrska, M., Tryniecki, L., Kornarzyński, K., Pietruszewski, S., & Gagość, M. (2016). Influence of magnetic field stimulation on the growth and biochemical parameters in Phaseolus vulgaris L. Journal of Microbiology, Biotechnology and Functional Food, 5(06), 548–551. https://doi.org/10.15414/jmbfs.2016.5.6.548-551

Nyakane, N. E., Markus, E. D., & Sedibe, M. M. (2019). The effects of magnetic fields on plants growth: A comprehensive review. International Journal of Food Engineering, 5(1), 79–87. https://doi.org/10.18178/ijfe.5.1.79-87

Osman, E. A. M., Abd El-Latif, K. M., Hussien, S. M., & Sherif, A. E. A. (2014). Assessing the effect of irrigation with different levels of saline magnetic water on growth parameters and mineral contents of pear seedlings. Global Journal of Scientific Researches, 2(5), 128–136. Retrieved from http://www.blue-ap.org/J/List/2/iss/volume 2 (2014)/issue 05/3.pdf#page=1&zoom=-41,792

Patil, A. G. (2014). Device for magnetic treatment of irrigation water and its effects on quality and yield of banana plants. International Journal of Biological Sciences and Applications, 1(4), 152–156. Retrieved from http://www.fulviofrisone.com/attachments/article/554/9030755.pdf

Pazur, A., Schimek, C., & Galland, P. (2007). Magnetoreception in microorganisms and fungi. Central European Journal of Biology, 2(4), 597–659. https://doi.org/10.2478/s11535-007-0032-z

Podleśna, A., Bojarżyczuk, J., & Podleśny, J. (2019). Effect of pre-sowing magnetic field treatment on some biochemical and physiological processes in faba bean (Vicia faba L. spp. Minor). Journal of Plant Growth Regulation, 38(3), 1153–1160. https://doi.org/10.1007/s00344-019-09920-1

Podleśny, J., Pietruszewski, S., & Podleśna, A. (2004). Efficiency of the magnetic treatment of broad bean seeds cultivated under experimental plot conditions. International Agrophysics, 18(1), 65–71. Retrieved from http://www.international-agrophysics.org/Efficiency-of-the-magnetic-treatment-of-broad-bean-seeds-ncultivated-under-experimental,106680,0,2.html

Podsiadło, C., & Skorupa, B. (2017). Impact of magnetized water on germination energy of seeds and weight of garden savory (Satureja hortensis L.), buckwheat (Fagopyrum esculentum L.), yellow lupine (Lupinus luteus L.) and winter rape (Brassica napus L.) seedlings. Polish Academy of Sciences and Applications. 3(2), 1241–1250. https://doi.org/10.14597/infraeco.2017.3.2.095

Radhakrishnan, R. (2019). Magnetic field regulates plant functions, growth and enhances tolerance against environmental stresses. Physiology and Molecular Biology of Plants, 25(5), 1107–1119. https://doi.org/10.1007/s12298-019-00699-9

Radhakrishnan, R., & Ranjitha Kumar, B. D. (2012). Pulsed magnetic field: A contemporary approach offers to enhance plant growth and yield of...
soybean. *Plant Physiology and Biochemistry, 51*, 139–144. https://doi.org/10.1016/j.plaphy.2011.10.017

Sadeghipour, O., & Aghaei, P. (2013). Improving the growth of cowpea (*Vigna unguiculata* L. Walp.) by magnetized water. *Journal of Biodiversity and Environmental Sciences, 3*(1), 37–43. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.653.5317&rep=rep1&type=pdf

Saunders, R. (2005). Static magnetic fields: animal studies. *Progress in Biophysics and Molecular Biology, 87*(2), 225–239. https://doi.org/10.1016/j.pbiomolbio.2004.09.001

Selim, A.-F. H., & El-Nady, M. F. (2011). Physio-anatomical responses of drought stressed tomato plants to magnetic field. *Acta Astronautica, 69*(7-8), 387–396. https://doi.org/10.1016/j.actaastro.2011.05.025

Shahin, M. M., Mashhour, A. M. A., & Abd-Elhady, E. S. E. (2016). Effect of magnetized irrigation water and seeds on some water properties, growth parameter and yield productivity of cucumber plants. *Current Science International, 5*(2), 152–164. Retrieved from http://www.currresweb.com/csi/csi/2016/152-164.pdf

Shine, M. B., Guruprasad, K. N., & Anand, A. (2011). Enhancement of germination, growth, and photosynthesis in soybean by pre-treatment of seeds with magnetic field. *Bio Electro Magnetics, 32*(6), 474–484. https://doi.org/10.1002/bem.20656

Surendran, U., Sandeep, O., & Joseph, E. J. (2016). The impacts of magnetic treatment of irrigation water on plant, water and soil characteristics. *Agricultural Water Management, 178*, 21–29. https://doi.org/10.1016/j.agwat.2016.08.016

Tahir, N., & Karim, H. (2010). Impact of magnetic application on the parameters related to growth of chickpea (*Cicer arietinum* L.). *Jordan Journal of Biological Sciences, 3*(4), 175–184. Retrieved from http://jjbs.hu.edu.jo/files/v3n4/ثحبلا مقر 6 modified.pdf

Turker, M., Temirci, C., Battal, P., & Erez, M. E. (2007). The effects of an artificial and static magnetic field on plant growth, chlorophyll and phytohormone levels in maize and sunflower plants. *Phyton - Annales Rei Botanicae, 46*(2), 271–284. Retrieved from https://www.zobodat.at/pdf/PHY_46_2_0271-0284.pdf

Vashisth, A., & Joshi, D. K. (2017). Growth characteristics of maize seeds exposed to magnetic field. *Bioelectromagnetics, 38*(2), 151–157. https://doi.org/10.1002/bem.22023

Yusuf, K. O., & Ogunlela, A. O. (2015). Impact of magnetic treatment of irrigation water on the growth and yield of tomato. *Notulae Scientia Biologicae, 7*(3), 345–348. https://doi.org/10.15835/nsb739532

Yusuf, K. O., & Ogunlela, A. O. (2017). Effects of deficit irrigation on the growth and yield of tomato (*Solanum lycopersicum*) irrigated with magnetised water. *Journal of Environmental Research, Engineering and Management, 73*(1), 59–68. Retrieved from https://erem.ktu.lt/index.php/erem/article/view/14138

Zablotskii, V., Polyakova, T., Lunov, O., & Dejneka, A. (2016). How a high-gradient magnetic field could affect cell life. *Scientific Reports, 6*(1), 37407. https://doi.org/10.1038/srep37407

Zaidi, N. S., Sohaili, J., Muda, K., & Sillanpää, M. (2014). Magnetic field application and its potential in water and wastewater treatment systems. *Separation & Purification Reviews, 43*(3), 206–240. https://doi.org/10.1080/15422119.2013.794148