INFLUENCE OF MAGNETIZED WATER ON THE GROWTH OF CORN (*ZEA MAYS*) SEEDLINGS

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Abstract. This study was conducted to evaluate the response of some growth characteristics of corn (*Zea mays*) seedlings for watering with magnetized water. For this experiment, we took corn seedlings and separated it into two sets. The first set watered with magnetized water and the second one was given tap water (control). The magnetized water was prepared by passing of tap water through the magnetization device at a relatively low speed and then collected into bottle for distribution. The seedlings were immediately watered after magnetization of water. The growth-related aspects of corn seedlings were investigated for 7 weeks. The results of the current study revealed that the seedlings' length, stem thickness, leaves number and leaves morphology were affected by magnetized water. Analysis of the results revealed the positive effects of magnetized water on the growth of corn seedlings. The seedlings that given magnetized water exhibited marked increases in shoot length, stem thickness and leaves number per seedling, and also changes of morphology of leaves over the control.

Key words: magnetized water, electromagnetic radiations, magnetic field, *Zea mays*, growth.

INTRODUCTION

For many years up to now, various researches have been conducted on showing the influence of magnetic field, in particular, magnetized water on living systems. The magnetized water is water made by passing of normal water through the magnetic field of certain intensity with a certain flow rate [1]. It is found that the treatment of water by magnetic field caused changes in some chemical and physical properties of water which lead to special functions [2, 12]. The differences between magnetized water and normal water have been previously mentioned with regard to conductivity, surface tension, activation energy, viscosity, hydrogen bond formation, water molecule size, evaporation, dissolved oxygen, uniformity of its structure and finally affects permeability of ion channels into the membrane [12].

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Magnetized water may increase cell membranes permeability and activity of calcium ions upsetting the balance of ion concentration in the cell and changing the intracellular pH [21].

The exact effect of magnetized water is still under investigation. Some of the studies showed that the growth of plants under the effect of magnetized water was enhanced while others stated that the growth was inhibited or unaffected.

Positive impact of magnetized water on germination and growth of plants mentioned in the study of Hozayn *et al*. [17], Moussa [25], Matwijczuk *et al*. [21], El Sayed [14], Aghamir *et al*. [2], Rashidi *et al*. [33], and Podsiadło and Skorupa [30]. They reported simulative effect of magnetized water on the development and morphological characteristics of the plants such as seed germination, shoot development, plant length, fresh weight, chlorophyll content and stem thickness. In addition, magnetized water enhanced the root function [8], influenced the chemical composition of plants [32], affect soil nutrient availability [24] and activate plant enzymes [11, 37]. Also, magnetized water increased the yield of wheat [17], pea [29], maize [40] and soybean [32]. In the study of Abou El-Yazied *et al*. [1], they reported that irrigation with magnetized water is friendly environmental techniques, therefore, it takes an important place in the list of environmental clean methods [26]. Magnetized water made plants more resistant to unfavorable environmental conditions [11] and improved the microorganism's content of soils [34].

On the other hand, Montriwat and Limpanuparb [22] in their study reported that watering Thai basil seeds with magnetized water had no observable effect on its length. In the study of Fateh *et al*. [15], they found out that magnetized water caused significant reduction in plumule and radicle length in compared with distilled water. The final effects of magnetically treated water depend on the degree and intensity of magnetic field, flowing water exposure time, water flow rate as well as plant genotype [30].

The main objective of this study was to identify the response of corn seedlings to magnetized water. Specifically, the study aimed to determine the growth characteristics of corn seedlings which were watered with magnetized water and tap water with regard to: length of shoot, thickness of stem, number, texture and color of corn leaves.

MATERIALS AND METHODS

The present investigation was conducted in March 2017 for 7 weeks at the laboratories of physics, biology & biotechnology department, Faculty of Science, Islamic University of Gaza to identify the influence of magnetized water on the growth of corn seedlings.

PLANT MATERIALS AND GROWTH CONDITIONS

There are two main considerations for the design of the current experiment, plant material and source of magnetic field. One week old of corn seedlings were used in this study. The reasons standing behind choosing the corn seedlings were found to be similar to the reasons mentioned by other studies [8, 9]. The tested seedlings were grown in a plastic container. We used the industrial soil (peat moss, SUBSTRATE SUB3 50/50, Nord Agri) that was free from heavy metals. During the course of the present experiment, the seedlings were not subjected to any type of pesticides. Table 1 shows the distribution of corn seedlings in tested group.

Table 1

The distribution of corn seedlings in each group

Type of experimental groups	**Number of corns in experimental groups**
Magnetized water	10
Tap water	10
Total	20

TREATMENTS

In our study, we took normal tap water and separated it into two parts. The first group was watered with magnetized water and the second one with normal tap water. Corn seedlings were grown under controlled conditions and watered in an organized method for a specific period of time similar to all tested seedlings.

In this experiment, magnetized water was prepared by passing of tap water through the magnetization device at a relatively low speed to prevent overflow, and then collected into bottle for distribution. The seedlings were immediately watered after magnetization of water, in meant, magnetized water was not stored or left for a specified period of time. The water was re-passed through the funnel only 7 times. Figure 1 shows the magnetization device, which consists of a permanent hard disk magnet affixed to the exterior surface of the funnel. The magnet had a circle shape (ring magnet), and the strength of this magnet was 125 mT. The choice of the magnetization device was conducted according to the study of El Sayed [14].

At the end of the experiment, shoot length, leaves number, stem thickness as well as morphology of leaves were determined. The length and thickness of the grown seedlings was carefully recorded using a ruler and capillary, respectively. The previous parameters were chosen because they indicate the growth status of seedlings under the tested growth condition. The investigated parameters are

considered good criteria to explain the changes induced by magnetized water whether in direct or indirect manner. During investigations, the reminder variables including atmospheric pressure, humidity and temperature were maintained constant.

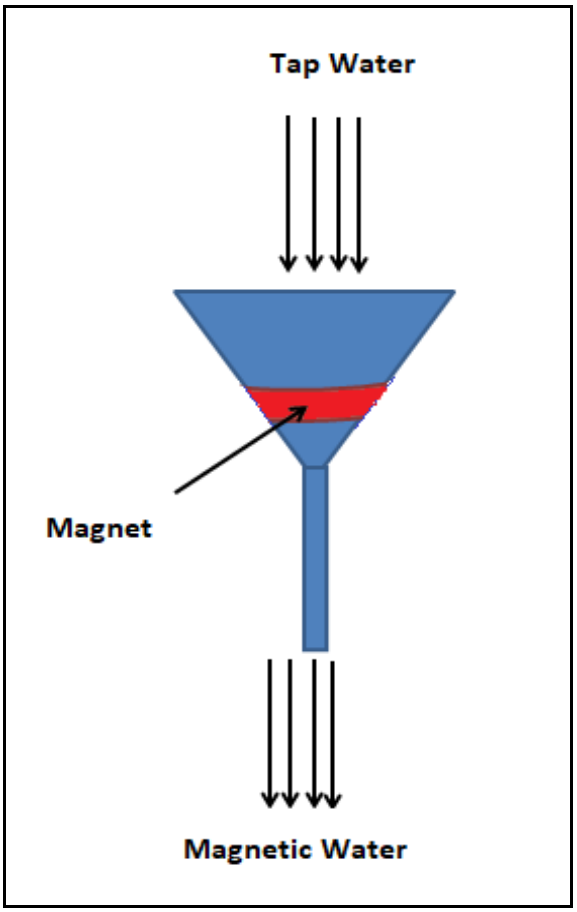

Fig 1. Construction of magnetized water treatment device.

MEASURING GROWTH RELATED CHARACTERISTICS

STATISTICAL ANALYSIS

The data was expressed as mean ± standard deviation. All analyses were made using SPSS computer program version 22.0 for Windows (Statistical Package for Social Sciences Inc, Chicago, Illinois). A two-tailed student t-test was applied to data to detect significant differences between different groups. Differences were considered significant at $p < 0.05$.

RESULTS

EFFECTS OF MAGNETIZED WATER ON SHOOT LENGTH

The results of the current experiment proved that the length of corn seedlings is significantly affected by the magnetized water, where the length of shoot was higher in seedlings grown under the effect of magnetic water than those grown without magnetized water (control). Figure 2 illustrates the average length of corn seedlings per week in each tested group. For each week, when seedlings watered with magnetized water show increases in length of seedlings as compared with the control.

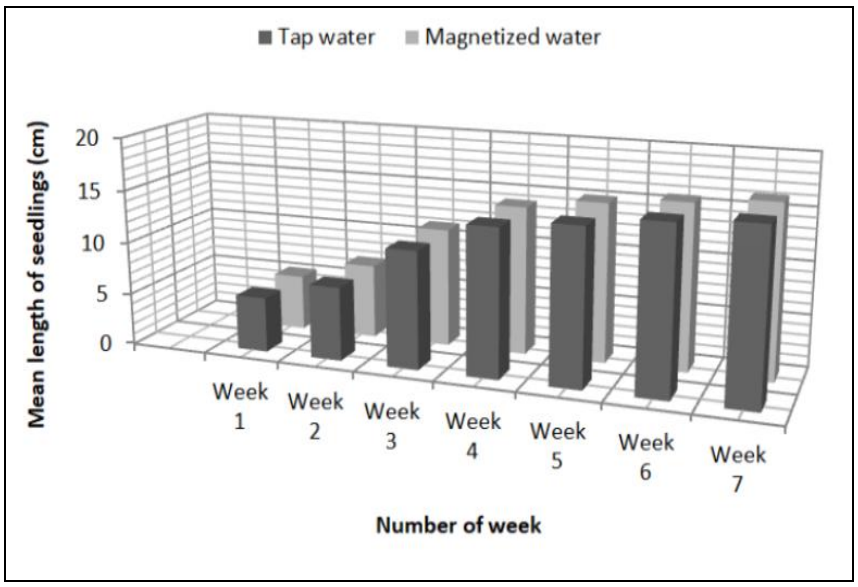

Fig. 2. The average of length (cm) for control and treated group per week.

Table 2 illustrate the results of shoot length at the end of the present study. The results showed that corn seedlings watered with magnetized water grew taller than seedlings watered with tap water. Analysis of the results showed that there is no statistically significant difference between two groups.

Table 2

The average of length (cm) of corn seedlings for control and treated groups

Experimental group	**Length at day 1**		**Length at day 49**	
	Mean	**SD**	**Mean**	**SD**
Magnetized water	5.00	0.18	16.35	2.37
Tap water	5.00	0.70	16.17	1.78

EFFECTS OF MAGNETIZED WATER ON STEM THICKNESS

The results which are presented in Table 3 shows a slightly variation in the stem thickness of corn seedlings watered with magnetized water after 49 days.

The results indicated that stem thickness was higher in seedlings grown with magnetized water than those grown without magnetized water. On average the percent of increments reached 3.12% in the above parameter. The results showed that the difference between the two corn groups was not statistically significant.

Table 3

The average of stem thickness (cm) of corn seedlings for control and treated groups

Experimental group	**Initial stem thickness**		**At day 49**	
	Mean	**SD**	**Mean**	**SD**
Magnetized water	0.35	0.06	0.66	0.12
Tap water	0.37	0.06	0.64	0.11

EFFECTS OF MAGNETIZED WATER ON LEAVES NUMBER

The results which are presented in Table 4 show variation in the number of leaves per seedling among the two groups at the start and at end of the experiment respectively. Treatment of corn seedlings with magnetically treated water showed a little increase when compared to those that were watered with normal tap water. The difference between two groups was not statistically significant and the seedlings of the two sets have almost the same number of leaves.

Table 4

The average of leaves number of corn seedlings for control and treated group

Experimental group	**Initial number**		**At day 49**	
	Mean	**SD**	**Mean**	**SD**
Magnetized water	3.30	0.48	5.20	1.22
Tap water	3.33	0.52	5.16	0.41

EFFECTS OF MAGNETIZED WATER ON LEAVES MORPHOLOGY

In morphological analysis of each tested seedlings, different changes were observed among exposed seedlings in comparison to control one with respect to morphology of their leaves. Table 5 gleans the response of corn seedlings to magnetized water with regard to morphology of leaves.

Table 5

Effects of magnetized water on leaves morphology of corn seedlings

Experimental group	At day 1		At day 49	
	Color	**Texture**	**Color**	**Texture**
Magnetized water	Bright green	Smooth	Dim green	Coarse
Tap water	Bright green	Smooth	Bright green	Smooth

The results of the current study found out that the leaves color of the seedlings that were watered with magnetically treated water was greener than the seedlings that were watered with tap water. Also, the corn seedlings that were watered with magnetized water were smoother than the corn seedlings in control group.

DISCUSSION

The overall results of the current study have cleared the positive effect of magnetized water on the growth-related characteristics of plants.

Obtained results indicated that shoot length of the magnetized water treated seedlings were higher than seedlings treated by tap water. These results are in agreement with that of Aghamir *et al*. [2], they conducted an experiment to evaluate the effects of magnetized water on corn seed germination under saline conditions. Results of this study showed that magnetized water significantly affected the corn growth and development parameters including the shoots length. Watering with magnetized water significantly increased the length of seedlings in comparison to untreated control seeds. In the study of Podsiadło and Skorupa [30], they observed a positive influence of magnetized water on the growth and development of buckwheat (*Fagopyrum esculentum* L.), yellow lupine (*Lupinus luteus* L.), winter rapeseed (*Brassica napus* L.), and garden savory (*Satureja hortensis* L.) seedlings after exposure their seeds to magnetized water. Also, in the study of Rashidi *et al*. [33], they reported that magnetized water has shown beneficial effects on the growth and development of plants. According to Hozayn and Qados [17], they reported that chickpea plants watered with magnetized water grew taller and heavier than plants watered with tap water. In the study of Yusuf and Ogunlela [38, 39], they found that tomato plant which was watered with magnetized water grew faster than those watered with tap water.

Similar observations have also been reported in common bean [25]; tomato (*Lycopersicon esculentum* (Mill) *cv. Castlrock*) [1, 27, 39]; wheat [17]; banana [6]; mustard [19]; Potato [4] and also after exposure the seeds of each *Pinus tropicalis M*. [23]; wheat, barley and tritical [36]; snow pea (*Pisum sativum* L *var. macrocarpon*) and Kabuli chickpea (*Cicer arietinum* L) [16]; sunflower [21]; broad bean (*Vicia faba*, L. *cv. Giza* 3) [14] to magnetic field.

The reason standing behind the stimulation in growth of treated plants is thought to be attributed to an effect of magnetized water on the induction of cell metabolism and mitosis [17]. Watering plants with magnetized water dissolves more nutrients because it lowers the surface tension of water, this lets more minerals be suspended in concentration. This buffers the pH and causes more minerals and nutrients to pass through the cell walls of roots which may allow roots to penetrate and grow larger [4, 35]. Magnetized water dissolves more nutrients into the root zone to become available to simulate the growth of plant. Moreover, magnetic field also decreases the effect of germination inhibitors due to increase in pH of the cell juice and can substitute for such expensive material [36]. In addition, applying of magnetized water reduced effects of saline and harmful minerals in the case of saline water [5].

On the other hand, our results were in contrast with some reports in which a decrease in several parameters including height was reported when watered with magnetized water as compared to control. In the study of Fateh *et al*. [15], they conducted a study to evaluate the effect of distilled and magnetized water as well as ultrasonic waves exposure times on fennel (*Foeniculum vulgare*) seed germination and seedling growth. Their results showed that types of water (distilled and magnetized water) had significant effect on all traits (germination percentage, germination rate and plumule and radicle lengths) except of germination percentage and radicle to plumule ratio. All studied traits decreased by using of magnetized water as compared with tap water except of radicle weight. They showed that magnetized water had significant inhibitory effect on germination rate. In addition, they found out that magnetized water caused significant reduction in length of each radicle and plumule in compared with distilled water. Montriwat and Limpanuparb [22], found that watering Thai basil (*Ocimum basilicum var. thyrsiflora*) seeds with magnetized water had no observable effect on the seedling length.

With respect to thickness of stem, watering with magnetically treated water significantly increased the stem thickness of treated seedlings. Such results are in accordance with Jogi *et al*. [19], they found that mustard plant watered with magnetized water exhibited highly significant increases in stem thickness as compare to the control plant. The findings of the current study seem to coincide with that stated by Yusuf and Ogunlela [38, 39] they found that tomato plant which was watered with magnetized water had bigger stem diameter than those watered with normal water. On the contrary, Osman *et al*. [27] found that stem diameter didn't affect significantly by watering of magnetized water.

Concerning to leaves color, the results of the present study revealed a positive effect on leaves color of corn seedlings that watered with magnetized water. The leaves of seedlings that watered with magnetized water were more greenish than those control. This difference may be due to various levels of pigments content including chlorophyll of corn seedlings in each group. The stimulatory effect of magnetized water may be due to the increase in photosynthetic pigments, endogenous promoters (IAA) and increase protein biosynthesis [33]. A similar finding was obtained by El Sayed [14], they demonstrated that the watering of broad bean plant

with magnetized water exhibited marked significant increase in the chloroplast pigments (chlorophyll a, chlorophyll b and carotenoids) and photosynthetic activity as compared to control plants. These results are also in agreement with those obtained by Shabrangi *et al*. [37]; Hozayn and Qados [17], Moussa [23]; El Sayed [14]; Jogi *et al*. [19]; Hozayn *et al*. [18], they showed an increase in chlorophyll content and carotenoids content specifically appeared after treatment with magnetized water. Also, Ajitkumar [6] observed that the color of leaves that used magnetically treated water was dark green compare to untreated plants.

The reasons standing behind increased photosynthetic and photochemical levels in tested seedlings were found to be similar to the reasons stated by other studies [11, 37]. Shabrangi *et al*. [37] reported that magnetized water has been linked to increases in photosynthetic pigments, endogenous promotors, total phenol and protein biosynthesis in plants. Watering with magnetized water exhibited marked significant increase in the photosynthetic pigments, photosynthetic activity, and translocation efficiency of the photoassimilates over the control. These results for increasing photosynthetic activity are in good agreement with that of Răcuciu *et al*. [31]. They showed an increase in chlorophyll and carotenoid content specifically appeared after treatment with magnetized water. Watering with magnetized water increased significantly the translocation rate as compared with the control.

Respecting to the effect of magnetized water on leaves number, the results indicated a slight difference among each corn groups at the end of the experiment. The number of leaves showed a significant increase as compared to control seedlings. Similar results were obtained by Osman *et al*. [27], they reported that the leaves number per plant were significantly increased by watering plants with magnetized water compared to those non-magnetic. El-Gizawy *et al*. [13] mentioned that the potato plants which were treated by magnetic field (30 mT) for 10 minutes produced the highest significant values for number of leaves per plant. The results are also in agreement with those obtained by Marks and Szecowka [20] on potato and Ahamed *et al*. [3] on sweet pepper. They reported that plants from magnetized seeds produced a greater number of leaves compared to untreated plants.

CONCLUSION

The overall results showed changes of growth characters of seedlings that were watered with magnetized water. Analysis of the results revealed the positive effects of magnetized water on the growth of corn seedlings. Corn seedlings that watered with magnetized water exhibited marked increases in shoot length, stem thickness and leaves number per seedling, and also changes of morphology of leaves over the control.

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REFERENCES

1. ABOU EL-YAZIED, A.A., A.M. EL-GIZAWY, S.M. KHALF, A. El-SATAR, O.A. SHALABY, Effect of magnetic field treatments for seeds and irrigation water as well as N, P and K levels on productivity of tomato plants, *Journal of Applied Sciences Research*, 2012, **8**, 2088–2099.
2. AGHAMIR, F., H.A. BAHRAMI, M.J. MALAKOUTI, S. ESHGHI, Magnetized water effects on seed germination and seedling growth of corn (*Zea mays*) under saline conditions, *American Journal of Life Science Researches*, 2015, **3**, 184–195.
3. AHAMED, M.E.M., A.A. ELZAAWEL, Y.A. BAYOUMI, Effect of magnetic field on seed germination, growth and yield of sweet pepper (*Capsicum annuum* L.), *Asian Journal of Crop Science*, 2013, **5**, 286–294.
4. AHMED, M.E., N.I. ABD EL-KADER, The influence of magnetic water and water regimes on soil salinity, growth, yield and tubers quality of potato plants, *Middle East Journal of Agriculture Research*, 2016, **5**, 132–143.
5. AHMADI, M., A. GHASEMNEZHAD, A. MAHOONAK, A. ASL, Effect of magnetized and saline water on the biomass yield of stevia (*Stevia rebaudiana* Bertoni.), *Advances in Bioresearch*, 2016, **7**, 158–166.
6. AJITKUMAR, G.P., Device for magnetic treatment of irrigation water and its effect on quality and yield of banana plants, *International Journal of Biological Sciences and Applications*, 2014, **1**, 152–156.
7. ALADJADJIYAN, A., Influence of microwave irradiation on some vitality indices and electroconductivity of ornamental perennial crops, *Journal of Central European Agriculture*, 2002, **3**, 271–276.
8. ALADJADJIYAN, A., Effect of microwave irradiation on seeds of lentils (*Lens Culinaris*, med.), *Romanian J. Biophys.*, 2010, **20**, 213–221.
9. ALATTAR, E., K. ELWASIFE, E. RADWAN, Y. ELRIFI, Response of corn (*Zea mays*), basil (*Ocimum basillcum*) and eggplant (*Solanum melongena*) seedlings to WI-FI radiation, *Romanian J. Biophys.*, 2017, **27**, 137–150.
10. ALATTAR, E., K. ELWASIFE, E. RADWAN, A. ALAGHA, Effect of microwave treated water on the growth of corn (*Zea mays*) and pepper (*Capsicum annuum*) seedlings, *Romanian J. Biophys.*, 2018, **28**, 115–124.
11. ALIKAMANOGLU, S., A. SEN, Stimulation of growth and some biochemical parameters by magnetic field in wheat (*Triticum aestivum* L.) tissue cultures, *African Journal of Biotechnology*, 2011, **10**, 10957–10963.
12. DANDAN, L., S. YAN, Effects of magnetized saline on growth and development of winter wheat seedlings, *Advance Journal of Food Science and Technology*, 2013, **5**, 1596–1599.
13. EL-GIZAWY, A.M., M.E. RAGAB, N.A. HELAL, A. EL-SATAR, I.H. OSMAN, Effect of magnetic field treatments on germination of true potato seeds, seedlings growth and potato tubers characteristics, *Middle East Journal of Agriculture Research*, 2016, **5**, 1–8.
14. EL SAYED, H.E.S.A., Impact of magnetic water irrigation for improve the growth, chemical composition and yield production of broad bean (*Vicia faba* L.) plant, *American journal of experimental agriculture*, 2014, **4**, 476–496.
15. FATEH E., H. NOROOZI, M. FARBOD, F. GERAMI, Assessment of fennel (*Foeniculum vulgare*) seed germination characteristics as influenced by ultrasonic waves and magnetic water, *European Journal of Experimental Biology*, 2012, **2**, 662–666.
16. GREWAL, H.S., B.L. MAHESHWARI, Magnetic treatment of irrigation water and snow pea and chickpea seeds enhances early growth and nutrient contents of seedlings, *Bioelectromagnetics*, 2011, **32**, 58–65.
17. HOZAYN, M., A. ABDUL QADOS, A.M. SAEED, Magnetic water application for improving wheat (*Triticum aestivum* L.) crop production, *Agriculture Biology Journal of North America*, 2010, **1**, 677–682.

18. HOZAYN, M., M.M. ABDALLHA, A.A. ABD EL-MONEM, A.A. EL-SAADY, M.A. DARWISH, Applications of magnetic technology in agriculture: A novel tool for improving crop productivity (1): Canola, *African Journal of Agricultural Research*, 2016, **11**, 441–449.
19. JOGI, P.D., R.D. DHARMALE, M.S. DUDHARE, A.A. AWARE, Magnetic water: a plant growth stimulator improve mustard (*Brassica nigra* L.) crop production, *Asian Journal of Bio Science*, 2015, **10**, 183–185.
20. MARKS, N., P.S. SZECOWKA, Impact of variable magnetic field stimulation on growth of aboveground parts of potato plants, *Int. Agrophysics*, 2010, **24**, 165–170.
21. MATWIJCZUK, A., K. KORNARZYNSKI, S. PIETRUSZEWSKI, Effect of magnetic field on seed germination and seedling growth of sunflower, *International Agrophysics*, 2012, **26**, 271–278.
22. MONTRIWAT, P., T. LIMPANUPARB, Exposure of plants to static electromagnetic fields: The early growth of basil and waxy corn, *Suranaree Journal of Science & Technology*, 2016, **23**, 333–341.
23. MOREJON, L.P., J.C. CASTRO PALACIO, L. VELAZQUEZ ABAD, A.P. GOVEA, Stimulation of *Pinus tropicalis M.* seeds by magnetically treated water, *International Agrophysics*, 2007, **21**, 173–177.
24. MOSTAFAZADEH, F., M. KHOSHRAVESH, S. MOUSAVI, A. KIANI, Effects of magnetized water on soil sulphate ions in trickle irrigation, *2nd International Conference on Environmental Engineering and Applications*, IACSIT Press, Singapore, 2011.
25. MOUSSA, H.R., The impact of magnetic water application for improving common bean (*Phaseolus vulgaris* L.) production, *New York Science Journal*, 2011, **4**, 15–20.
26. NIMMI, V., G. MADHU, Effect of pre-sowing treatment with permanent magnetic field on germination and growth of chilli (*Capsicum annum.* L.), *International Agrophysics*, 2009, **23**, 195–198.
27. OSMAN, E.A., K. M. ABD EL-LATIF, S.M. HUSSIEN, A.E. SHERIF, 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*, 2014, **2**, 128–136.
28. PIETRUSZEWSKI, S., E. MARTINEZ, Magnetic field as a method of improving the quality of sowing material: a review, *International Agrophysics*, 2015, **29**, 377–389.
29. PODLESNY, J., M. GENDARZ, Effect of magnetic-conditioned water on growth, development and yielding of two Pea genotypes, *Acta Agrophysica*, 2008, **12**, 767–776.
30. PODSIADLO, C., B. SKORUPA, 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*, Cracow Branch, 2017, pp. 1241–1250.
31. RĂCUCIU, M.I., S.I. MICLĂUȘ, D.E. CREANGĂ, The response of plant tissues to magnetic fluid and electromagnetic exposure. *Romanian J. Biophys.*, 2009, **19**, 73–83.
32. RADHAKRISHNAN, R., B. KUMARI, Pulsed magnetic field: A contemporary approach offers to enhance plant growth and yield of soybean, *Plant Physiology and Biochemistry*, 2012, **51**, 139–144.
33. RASHIDI, S., A. YADOLLAHPOUR, S. SHIRALI, G. RAJASHEKAR, Magnetized water treatment: Reviewing the environmental applications, *International Journal of Pharmacy & Technology*, 2016, **8**, 11431–11441.
34. RATUSHNYAK, A.A., M.G. ANDREEVA, O.V. MOROZOVA, G.A. MOROZOV, M.V. TRUSHIN, Effect of extremely high frequency electromagnetic fields on the microbiological community in rhizosphere of plants, *International Agrophysics*, 2008, **22**, 71–74.
35. RAWABDEH, H., S. SHIYAB, R. SHIBLI, The effect of irrigation by magnetically water on chlorophyll and macro-elements uptake of pepper (*Capsicum annuum* L.), *Jordan Journal of Agricultural Sciences*, 2014, **10**, 205–214.
36. SELIM, M., Application of magnetic technologies in correcting underground brackish water for irrigation in the arid and semi-arid ecosystem, *The 3rd International Conference on Water Resources and Arid Environments*, 2008, http://www.icwrae-psipw.org/images/stories/2008/Environment/6.pdf.

37. SHABRANGI, A., A. MAJD, M. SHEIDAI, Effects of extremely low frequency electromagnetic fields on growth, cytogenetic, protein content and antioxidant system of *Zea mays* L, *African Journal of Biotechnology*, 2009, **10**, 9362–9369.
38. YUSUF, K.O., A.O. OGUNLELA, Impact of magnetic treatment of irrigation water on the growth and yield of tomato, *Notulae Scientia Biologicae*, 2015, **7,** 345–348.
39. YUSUF, K.O., A.O. OGUNLELA, Effects of deficit irrigation on the growth and yield of tomato irrigated with magnetized water, *Environmental Research, Engineering and Management*, 2017, **73**, 59–68.
40. ZEPEDA, R.B., C.A. HERNANDEZ, F.L. SUAZO, A.P. DOMINGUEZ, A.O. CRUZ, E.O. MARTINEZ, L.M. HERNANDEZ, Physical characteristics of maize grain and tortilla exposed to electromagnetic field, *International Agrophysics*, 2001, **25**, 389–393.