INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 5, No. 6, p. 148-155, 2014

RESEARCH PAPER OPEN ACCESS

Electromagnetic application for stimulation of wheat seed germination and early seedling growth

Farshad Golshani[1], Mohammad R. Asgharipour[2*]

[1]*Zabol University of Medical Sciences, Zabol, Iran*

[2]*College of Agriculture, University of Zabol, Zabol, Iran*

Key words: Stationary magnetic field, wheat, germination.

http://dx.doi.org/10.12692/ijb/5.6.148-155 Article published on September 20, 2014

Abstract

The effects of electromagnetic field treatments of wheat seeds on germination and early seedling growth were studied under controlled conditions. Dried seeds were exposed to magnetic field of strength from 0 to 1.5 T in steps of 0.3 T for different time periods of 5 to 20 min in steps of 5 min. Thereafter, the seeds were incubated for a total period of 7 days to germinate. The germinating seeds were counted every 24 h during the incubation period of 7 days. Germination percentage, mean germination time, vigor index were evaluated. Most of seed treatments resulted in improved germination speed and spread, root and shoot length, seed soluble sugars and a-amylase activity. The results indicated that the effects of treatment depended on strength and period of exposure to magnetic field. Treatment of wheat seeds in these magnetic fields increased mean germination time, seedling length and seedling dry weight. The greatest increases of the various treatments were obtained for plants exposed to 0.3 and 1.2 T for 10 min. The higher enzyme activity in magnetic-field-treated wheat seeds could be triggering the fast germination and early vigor of seedlings. The results suggest that magnetic field treatments of wheat seeds have the potential to enhance germination, early growth and biochemical parameters of seedlings.

* **Corresponding Author:** Mohammad R. Asgharipour ✉ m_asgharipour@uoz.ac.ir

Introduction

Modern agricultural efforts are now in search of an efficient ecofriendly production technology based on physical treatment of seeds to increase the seedling vigor and crop establishment. Exposure of seeds to magnetic fields is one of the safe and affordable potential physical pre-sowing treatments to enhance post-germination plant development and crop stand (Asgharipour and Razavi Omrani, 2011).

All plants on earth live under an electric and magnetic field because the earth is a magnet (Muntz, 1996) and there is an electric field between clouds and the earth (Nagarajan *et al.,* 2003). It has been reported that external electric and magnetic fields influence both the activation of ions and the polarization of dipoles in living cells (Shewry *et al.,* 1995). Investigations into electromagnetic effects on plants have already been carried out in Russia (Ramakrishna and Ramakrishna Rao, 2005) with some remarkable results (Pandita *et al.,* 2003). The optimal external electromagnetic field could accelerate the activation of seed germination (Bhatnagar and Deb, 1978). But the mechanism of these actions is still poorly understood (Ramakrishna and Ramakrishna Rao, 2005). Electric and/or magnetic treatments are assumed to enhance seed vigor by influencing the biochemical processes that involve free radicals and by stimulating the activity of proteins and enzymes (Shewry *et al.,* 1995).

Germination and seedling emergence demand high energy for respiration of the seed embryo and cotyledon. The mobilization of seed storage proteins represents one of the most important post-germination events in the growth and development of the seedling. Proteolytic enzymes play a central role in the biochemical mechanism of germination (Shewry *et al.,* 1995; Muntz, 1996). These proteases increase in the early stages of germination and later decrease (Ramakrishna and Ramakrishna Rao, 2005). Bhatnagar and Deb (1978) reported that a-amylaseactivityin wheat seeds exposed to magnetic fields reached maximum values during imbibition and then subsequently declined. Priming seeds of carrot and tomato improved seedling vigor and was related to the level of dehydrogenase activity (Nagarajan *et al.,* 2003; Pandita *et al.,* 2003).

Field tests report greater than 10% increase in the field of maize and wheat, after submitting the seeds to carefully controlled electric fields (Nagarajan *et al.,* 2003). These effects were mainly attributed to the field-induced intensification of the biological processes in seeds. The crop increase could also be related to the sterilizing effect of high-voltage application.

The present study using wheat seeds is focused on the magnetic field strength and duration of exposure in wheat seed germination and early seedling growth.

Materials and methods

Plant materials

The experiment was carried out in April 2010 at the Biotech Research Center of the University of Zabol, Zabol, I.R. Iran. Certified seeds of wheat (*Triticum aestivum*) variety, Roshan, being widely planted all over Iran, was used in this study. Seeds were kindly provided by Zabol Agricultural Research Center. Prior to germination, seeds were disinfected with 3% Formaldehyde for 10 minutes, washed thoroughly under tap water and finally with distilled water.

Seed moisture content was determined by oven drying seeds at 85 °C to constant weight. Moisture content (%) was calculated as $[(W1–W2/W2] \times 100$, where W1 was the initial weight of the seed and W2 was the final weight of the seed after drying. A moisture content of 7.0% was used for all treatments and experiments.

Magnetic Treatment

An electromagnetic field generator with variable horizontal magnetic field strength (0.3–1.5T) with a gap of 5 cm between pole pieces was fabricated. The pole pieces were cylindrical in shape, 9 cm in diameter and 16 cm in length. ADC power supply (80V/10A) with a continuously variable output current was used for the electromagnet.

Wheats seeds were exposed to the magnetic field of 0 to 1.2Tin steps of 0.3T for 5, 10, 15 and 20 min for all field strengths in a cylindrical-shaped sample holder of 20 cm3 capacity, made of anon-magnetic thin transparent plastic sheet. 50 visibly sound, mature, healthy seeds were held in the plastic container at a volume between the poles of the electromagnet having a uniform magnetic field for the required duration.

Seed Germination

After electromagnetic field treatments 25 wheat seeds were then germinated in sterilized Petri dishes, 100 mm in diameter, on Whatmann filter-paper moistened with 10 mL of either double-distilled water. Petri dishes were subsequently kept in the dark, at 25 °C, for a span of 10 days. The solutions were renewed after 3 days. After 10 days, germinated seeds were grouped as normal, abnormal, fresh un-germinated and dead seeds. The germination percentage was calculated based on normal seedlings. Ten such seedlings from each replicate were randomly selected to measure shoot and root length. Dry weight was also evaluated after drying the specimens (10 seeds) for 72 hours at 76 °C.

During the experiment, germinated seeds were counted on a daily. Seed germinability was assessed by the final cumulative percentage of germination at the end of the tests. Here, germination was considered only when the radicles were longer than 2 mm. Seedling vigor was calculated following Abdul-Baki and Anderson (1973) as;

Vigor index I = Germination% × Seedling length (Root + Shoot)

Vigor index II = Germination% × Seedling dry weight (Root + Shoot)

Mean germination time was calculated according to the equation below (Nascimento, 2003):

$$\text{Mean germination time} = \sum \left(\frac{N_i \times 100}{D_i} \right)$$

Where *Di* is the number of days after starting the experiment and *Ni* represent the total number of germinated seeds on the *i*th day.

Statistical Analysis

The data were analyzed using SPSS Ver. 8 software. Two factor analysis of variance (ANOVA) was performed on a factorial design, “magnetic field” and “duration of exposure”. The significant levels of difference between the treatments for germination percentage, mean germination time, seed weight, radicle length, radicle weight and radicle weight ratio among magnetic fields, duration and their interactions were expressed as significant at levels of p≤0.05 and p≤0.05.Conventionally, if $P < 0.05$, the result is statistically significant and if $P < 0.01$, the result is highly significant with more confidence of true effect.

Results and discussion

Exposure of wheats seeds to different intensities of magnetic fields prior to germination significantly increased germination-related characters, such as germination percentage, mean germinationtime, shoot and root length, seedling dry weight and calculated vigor indices. The improvement over untreated control seeds was 5–11% for germination, 9–15% for mean germination time, 6–41% for shoot length, 16–80% for root length, 12– 57% for total seedling length and 5–13% for seedling dry weight. The calculated vigor indices I and II also increased by 18–74% and 10–25%, respectively. The percent enhancement of different parameters was not linearly related to magnetic field strength. Among the various magnetic treatments, 0.3, 0.9 and 1.2 T for 10 min exposure were more effective than others in increasing most of the seedling parameters. Magnetic field exposure time of 5-20 min significantly increased germination characteristics. However, exposure 10 min duration was more effective compared to the others in enhancing seed germination characters.

The interaction of magnetic field and duration of exposure are provided in Tables1–3. With most of the field strengths, enhancement of germination percent was noted for the 10 min duration. mean germination time was significantly higher than control in 0.3 T (10 and 20 min) 0.6 T (5 min), 0.9 T (15 min), 1.2 T (5 and 10 min) and 1.5 T (10 and 15 min). Shoot length of seedlings showed significantly greater response for most fields and exposure times. However, there was a reduction in shoot length compared to unexposed controls for some exposures, including 0.6 T (5, 15 and 20 min) and 0.9 T (20 min) and 1.2 T (5 min). The maximum value was observed for 10 min exposure of 1.2 T followed by 0.3 and 1.5 T fields. A similar response was obtained for seedling root length in 0.3, 1.2 and 1.5 T fields for 10 min exposure. Root length was reduced compared to controls in 0.6 T (5, 15 and 20 min), 0.9 T (20 min) and 1.2 T (5 min) fields. Seedling dry weight was greatest in 0.3, 1.2 and 1.5 T for 10 min exposure and the values were significantly higher than the controls in 0.3 T (5, 10 and 20 min) 0.6 T (10 min), 0.9 T (5 min), 1.2 T (10 min) and 1.5 T (5 and 10 min) treatments. Seedling vigor I based on seedling length and germination percent showed a trend similar to seedling shoot and root length. Seedling vigor II values based on seedling dry weight and germination percent were highest for 0.3, 1.2 and 1.5 T magnetic fields at 10 min exposure.

From the analysis of the data, it appeared that, when all germination characteristics were taken into consideration, the best results were observed in 0.3, 1.2 and 1.5 T magnetic fields for 10 min exposures.

Table 1. Effect of different doses and duration of magnetic field exposure of lentil seeds on shoot length, root length total seedling length and seedling dry weight.

Parameters	Magnetic field strength (T)	Control	5 min	10 min	15 min	20 min
Shoot length (cm)	0	8.5	8.5	8.5	8.5	8.5
	0.3	8.8	12.2	13.5	6.2	4.8
	0.6	5.1	11.1	12.6	10.2	6.4
	0.9	10.1	12.1	11.8	10.1	7.4
	1.2	6.2	10.2	9.5	8.9	8.1
	1.5	8.3	9.4	10.1	9.1	9.8
LSD	0.6					
Root length (cm)	0	7.3	7.3	7.3	7.3	7.3
	0.3	10.8	14.9	9.9	12.6	10.1
	0.6	6.3	13.6	7.6	5.9	4.7
	0.9	12.3	12.2	13.0	8.1	3.2
	1.2	7.6	14.8	12.3	11.3	8.4
	1.5	10.2	15.0	10.9	9.9	4.9
LSD	1.8					
Total seedling length (cm)	0	15.8	15.8	15.8	15.8	15.8
	0.3	19.6	27.1	18.0	22.9	15.6
	0.6	11.4	24.7	13.8	10.7	17.2
	0.9	22.4	22.2	23.6	14.7	18.1
	1.2	13.8	26.9	22.4	20.5	14.3
	1.5	18.5	27.3	19.8	18.0	12.1
LSD	4.3					
Seedling dry weight (g)	0	0.041	0.041	0.041	0.041	0.041
	0.3	0.025	0.053	0.025	0.030	0.023
	0.6	0.048	0.048	0.48	0.050	0.032
	0.9	0.030	0.057	0.32	0.048	0.044
	1.2	0.042	0.058	0.043	0.042	0.039
	1.5	0.042	0.58	0.32	0.039	0.049
LSD	0.002					

Discussion

Exposure of different magnetic fields in general stimulates the germination of wheat seeds (Tables 1-3). Such enhanced performance of seeds exposed to magnetic fields has been reported previously by workers dealing with various crop seeds (Aladjadjiyan, 2002; Fischer *et al.*, 2004; Florez *et al.*, 2007). Vashisth and Nagarajan (2007) noted that there is a significant increase in germination, seedling vigor and shoot/root growth in maize and chickpea seeds exposed to static magnetic fields. Florez *et al.* (2007) reported faster germination of maize seeds when exposed to magnetic field of 125 or 250 mT for varying periods of time. Total length and fresh weight of 10-d-old seedlings were highest when their seed-lot was exposed to 125 or 250 mT. Fischer *et al.* (2004) reported that wheat seedlings exposed to magnetic fields showed small but significant increases in total fresh weight, whereas dry weight and germination rates remained unaffected.

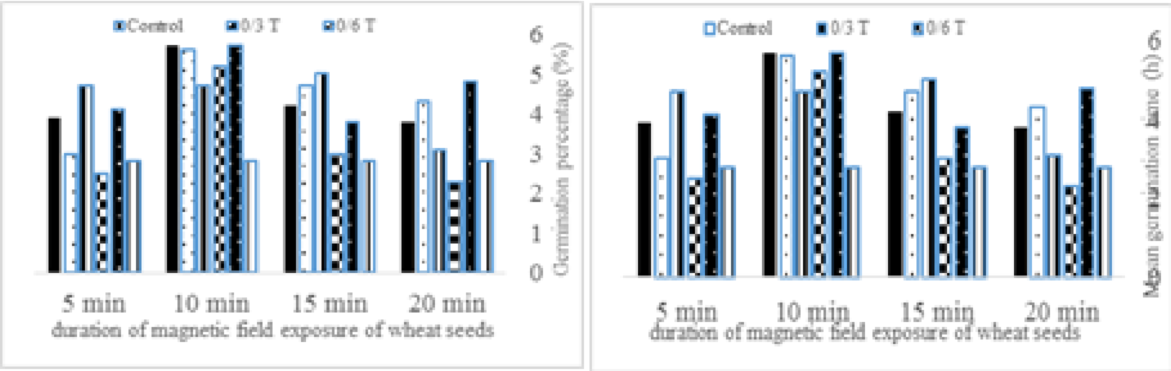

Fig. 1. Effect of different doses and duration of magnetic field exposure of wheat seeds on germination percentage and mean germination time.

The interaction of magnetic field and exposure time indicates that certain combinations of magnetic field and duration, such as 0.3, 0.6 and 1.5 T for 10 min, are highly effective in enhancing germination (Tables 1-3).

This observation indicates that the internal energy of the seed responds positively when there is an appropriate combination of magnetic field and exposure time (Bhatnagar and Deb, 1977). Kavi (1983) reported that, in ragi (*Eleusinecoracana*) seeds exposed to 100 mT, a magnetic field changed the internal potential energy and suggested that by selecting a suitable combination of magnetic field and exposure time, it may be possible to obtain higher yields.

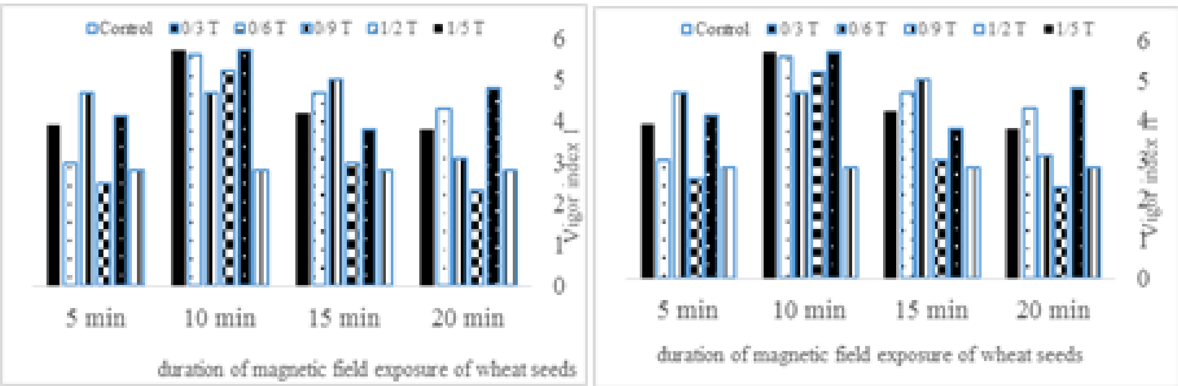

Fig. 2. Effect of different doses and duration of magnetic field exposure of lentil seeds on vigor index I and vigor index II.

The reduced conductivity of leachate from seeds exposed to 50, 200 and 250 m T fields compared with control (Table1) indicates greater seed coat membrane integrity in these seeds. However, exposure of barley seeds to a 37.5 m T field had no effect on leakage of cellular electrolytes (Gusta *et al.*, 1978). In the field, the percent seedling mergence improved and the field emergence index increased significantly compared with controls; this is further supported our laboratory data. Similar observations have been reported in maize (Florez *et al*.., 2007), in rice (Carbonell *et al.,* 2000), in wheat (Bhatnagar and Deb, 1977; Martinez *et al.,* 2002), and in barley (Martinez *et al.,* 2000). Podlesny *et al.* (2004, 2005) validated the positive effect of magnetic treatment on the germination and emergence of both broad bean and pea cultivars. As are result of magnetic treatment, plant emergence was more uniform and emergence occurred 2–3 d earlier than the control. Such an increase in shoot and root weights of 1-month-old plants, and significantly improved root characteristics in plants from magnetically exposed seeds may lead to better performance under limited water availability and increased water uptake from the soil (Richard and Passioura, 1981). Rajendra *et al.* (2005) observed significant increases in the mitotic index as well as H-thymidine in corporation in to DNA in seeds of *V. faba* exposed to a 100 mT power frequency electromagnetic field. There are clear indications of enhanced growth of seedlings exposed to a magnetic field. The authors suggest that the ion–cyclotron resonancemay interfere with the Ca2+ ion sequestering and there by enable an increase in free Ca2+ concentrations in the seedling system. The increased Ca2+ concentration possibly signals the cell to enter in to an early mitotic cycle. This is supported by the observation that increased uptake of Ca2+ ions in rice seedlings grown from seeds exposed to a pulsed magnetic field was found responsible for greater leaf growth and meristematic tissues in stems and roots (Saktheeswari and Subrahmanyam, 1989). The improved root length and root surface area help in extracting moisture from the soil. Among all magnetic field treatments with wheat seeds, 200m T exposure for 2h yielded the best results. Kiranmai (1994) reported that 2000 Gauss (200 mT) magnetic field exposure for 90 min produced positive mutations in wheat in terms of germination, plant height, days to flowering, days to maturity, yield of plant and oil content and oil quality.

Conclusion

Exposure of dry wheat seeds to static magnetic fields significantly increased germination, mean germination time, seedling length and dry weights compared to unexposed controls. Among the various combinations of field strength and duration, 0.3 and 1.2 T for 10 min exposure yielded superior results. The improved functional root parameters suggest that magnetically treated wheat seeds can be used in practical agriculture under rainfed farming, where better root growth will enable extraction of moisture from deeper soil layers.

References

Asgharipour MR, Razavi Omrani M. 2011. Effects of seed pretreatment by stationary magnetic fields on germination and early growth of lentil. Australian Journal of Basic and Applied Sciences **5(12),** 1650-1654.

Abdul-Baki AA, Anderson JD. 1973. Vigour determination in soybean by multiple criteria. Crop Sciences **10,** 31-34.
http://dx.doi.org.10.2135/cropsci1973.0011183X0013000060013x

Aksenov SI, Grunina TY, Goryachev SN. 2001. Features of low-frequency magnetic fields effects on imbibition of wheat seeds at its different stages. Biofizika **46,** 1127-1132.

Aladjadjiyan A. 2002. Study of the influence of magnetic field on some biological characteristics of *Zea mays*. Journal of Central European Agriculture, **3(2),** 89-94.
http://dx.doi.org/10.1134/S0006350907020157.

Alexander MP, Dijode SD. 1995. Electromagnetic field, a novel tool to increases germination and seedling vigour of conserved onion (*Allium cepa* L.) and rice (*Oryza sativa* L.) seeds with low viability. Plant Genetics Resources Newsletter **104,** 1-5.
http://dx.doi.org/10.1134/S0006350907020157.

Bhatnagar D, Deb AR. 1977. Some effect of pre-germination exposure of wheat seeds to magnetic fields: effect on some physiological process. Seed Research **5(2),** 129-137.
http://dx.doi.org/10.5897/AJB12.192.

Carbonell MV, Martinez E, Florez M, Maqueda R, Lopez-Pintor A, Amaya JM. 2008. Magnetic field treatments improve germination and seedling growth in *Festuca arundinacea* Schreb and *Lolium perenne* L. Seed Science and Technology **36,** 31-37. http://dx.doi.org/10.4161/psb.6.11.17720.

De Souza A, Garcia D, Sueiro L, Gilart F, Porras E, Licea L. 2006. Pre-sowing magnetic treatments of tomato seeds increase the growth and yield of plants. Bioelectromagnetics **27,** 247-257. http://dx.doi.org/10.1002/bem.20206.

Fischer G, Tausz M, Kock M, Grill D. 2004. Effect of weak 162/3 HZ magnetic fields on growth parameters of young wheat and wheat seedlings. Bioelectromagnetics **25(8),** 638-641. http://dx.doi.org/10.1002/bem.20058.

Florez M, Carbonell MV, Martinez E. 2007. Exposure of maize seeds to stationary magnetic fields: effects on germination and early growth. Environmental and Experimental Botany **59,** 68-75. http://dx.doi.org/10.1016/j.envexpbot.2005.10.006.

Florez M, Carbonell MV, Martinez E. 2004. Early sprouting and first stages of growth of rice seeds exposed to a magnetic field. Electromagnetics and Biological Medicine **23(2),** 157-166. http://dx.doi.org/10.1081/LEBM-200042316.

Florez M, Carbonell MV, Martinez E. 2007. Exposure of maize seeds to stationary magnetic fields: Effects on germination and early growth. Environmental and Experimental Botany **59,** 68-75. http://dx.doi.org/10.1016/j.envexpbot.2005.10.006.

Harichand KS, Narula V, Raj D, Singh G. 2002. Effect of magnetic fields on germination, vigour and seed yield of wheat. Seed Research **30(2),** 289-93. http://dx.doi.org/10.2478/v10247-012-0004-z.

Kavi PS. 1983. The effect of non-homogeneous, gradient magnetic field on the magnetic susceptibility values of in sitragi (*EleusinecoracanaG*aertn) seed material. Mysore Journal of Agricultural Sciences **17,** 121-123.

Likholat TV, Yashkichev VI, Krylov PP. 1999. Effects of Low-Frequency Magnetic Field on Germination of Seeds with Low Germinating Capacity, *Tez. dokl. II S"ezdabiofizikov Rossii* (Abst. II Meet. of Biophysicists of Russia), Moscow: Institutbiofiziki **3,** 811-812.

Mano J, Nakahara T, Torii Y, Hirose H, Miyakoshi J, Takimoto K. 2006. Seed deterioration due to high humidity at high temperature is suppressed by extremely low frequency magnetic fields. Seed Science and Technology **34,** 189-192.

Martinez E, Carbonell MV, Amaya JM. 2000. A static magnetic field of 125 mT stimulates the initial growth stages of barley (*Hordenumvulgare L.*). Electro and Magnet **19(3),** 271-277. http://dx.doi.org

Nascimento WM. 2003. Muskmelon seed germination and seedling development in response to seed priming. Scientia Agricola **60(1),** 71-75. http://dx.doi.org/10.1002/bem.20206.

Podlesny J, Misiak L, Podlesna A. 2004. Concentration of free radicals in pea seeds afterpre-sowing treatment with magnetic field. International Agrophysics **18,** 261-267.

Rajendra P, Nayak HS, Sashidhar RB, Subramanyam C, Devendarnath D, Gunasekaran B. 2005. Effects of power frequency electromagnetic fields on growth of germinating *Viciafaba* L., the broad bean. Eletromagnetics and Biological Medecine **24,** 39-54. http://dx.doi.org/10.1081/JBC-200055058.

Sirotina LV, Sirotin AA, Travkin MP, Shatilov MP. 1973. Effects of Magnetic Field on the Growth Processes in Germinating Millet Seeds, *Mater. 2-go Vses. Simp. "Vliyanieestestvennykh I slabykhiskus* *stvennykh magnitnykh poleina biologiches kieob"ekty"* (Proc. 2nd All-Union Symp. Effects of Nature and Weak Artificial Magnetic Fields on Biological Objects), Belgorod, 85-87 P.

Soltani F, Kashi A, Arghavani M. 2006. Effect of magnetic field on *Asparagus officinalis* L. seed germination and seedling growth. Seed Sciences and Technology **34**, 349-353.
http://dx.doi.org/10.12692/ijb/3.4.199-207.

Vashisth A, Nagarajan S. 2008. Exposure of seeds to static magnetic field enhances germination and early growth characteristics in chickpea (*Cicer arientum* L.). Bioelectromagnetics **29**, 571-578.