

Effect of low frequency magnetic field (LFMF) on seed quality of radish (*Raphanus sativus* L.) seeds

Xianzong XIA^{1*}, Gregorio PADULA¹, Leszek KUBISZ²,
Roman HOŁUBOWICZ¹

¹Poznań University of Life Sciences, Department of Plant Pathology, Seed Science and Technology, ul. Dąbrowskiego 159, 60-594, Poznań, Poland; xianzongx@foxmail.com (*corresponding author); gregorio.padula@tokitasementi.it; roman.holubowicz@up.poznan.pl

²Poznań University of Medical Sciences, Department of Biophysics, Collegium Chemicum, ul. Grunwaldzka 6, 60-780 Poznań, Poland; lkubisz@ump.edu.pl

Abstract

In recent years, the application of magnetism in agriculture has been paid more and more attention to, especially in the field of its treatment on the seed germination and physiological indexes of seedlings grown out of them. In this experiment, the radish (*Raphanus sativus* L.) seeds of two cultivars 'Carmen' and 'Szkarłatna z Białym Końcem' were treated by 20 mT low frequency magnetic field (LFMF) for 10, 30 and 60 minutes, respectively. The MF was generated from a Viofor JPS Delux - a patented device adopted from the routine medical magnetic therapy. By measuring their seed germination rate (energy), seedling length and fresh weight, it was proved that LFMF improved the seed quality of both radish cultivars and the best results were received for the longest exposing time. The received that way results were similar as reported for priming of radish seeds. The developed treatment has a great potential in replacing traditional seed priming methods. However, for its commercial use, for selected crops and cultivars, further research is still needed.

Keywords: seedling fresh weight; seed germination; seedling length; seed priming

Introduction

With the development of modern science and technology, magnetism has attracted the attention of scientists. Soon, a new part of magnetism as a science that studies the interrelationships and interactions between the magnetism and plant's properties has been developed. It has been widely used in the fields of medicine, agriculture, environmental protection and biological engineering (Yao and Shen, 2015). In the 1960s to 1970s, magnetic achievements began to be applied to agricultural production. Direct treatment of plant seeds with magnetic fields has been one of the main methods used in agricultural fields by magnetism. Many scholars have done a lot of exploratory work on the magnetic field (MF) treatment of seeds of various crops and its biological effects. They have proved that the application of MF to crop seeds is an effective way to increase crop yield (Qi *et al.*, 2015; Ren *et al.*, 2015). The use of artificial MF treatment on the seeds did improve their germination and vigour, promote their emergences, modify some botanical characters and increase final yield and its quality of plants grown out from them. Moreover, it enhanced their stress resistance (Fan *et al.*,

2007; Hua *et al.*, 2008; Xu and Zheng, 2009; Sun *et al.*, 2010; Bao and Yun, 2010; Sakthivel *et al.*, 2013). The advantages of small physiological damage, low cost, easy operation and application have been proved by many experiments. Moreover, this technology produces no pollution and has high input-output ratio (Liu and Yu, 2010; Pan *et al.*, 2015; Chang and Jiao, 2016). Crop seed MF processing technology is increasingly attracting attention as a supplement to space plant breeding technology.

The MF acts as a stimulating factor that affects plants from all levels of electrons, molecules, cells and metabolism. In the fields of medicine, magnetism has entered the stage of specific application; in the field of agricultural science, the influence of MF on crops and its yield-increasing effect are being extensively explored. To date, MF treatment of crop seeds has been a very active field in magnetism, and it is expected that this eventually will lead to an improvement in crop physiological activity and an increase in yield.

Seed priming is today one of the classical and routinely applied methods to improve seed quality in commercial seed processing and trade. By using water or mineral salt solution, the seed germination is initiated and then, after a certain time, the growth of embryo radicle is stopped before its seed coat protrusion. At this stage, the ready seeds are either sell and then sown or dried back and stored for later selling. The procedure results in improving the both seed germination rate and field emergences evenness. A big disadvantage of the method is a necessity to precisely adjust exact conditions of treatment for seeds of each species, cultivar or even a seed lot (Vanangamudi *et al.*, 2013; Holubowicz, 2016). When priming radish seeds, the germination and vigour indexes were bigger than in the check seeds (Li, 2010; Song *et al.*, 2015) and the seedlings had also higher dry weight than the check plants (Maroufi *et al.*, 2011).

The purpose of the experiment was to find out, if LFMF could improve both seeds germination rate and seedlings' length and weight the same way as during their priming.

Materials and Methods

The seeds of two radish cultivars: 'Carmen' (C) and 'Szkarlata z Białym Końcem' (SBK) used for this experiment were arranged by Polish plant breeding and seed production company W. Legutko. Both cultivars have been commercially used for gardeners in Poland. Their seeds parameters met the professional market production standards.

The LFMF was generated from a Viofor JPS Delux - a patented device adopted from the routine medical magnetic therapy (Figure 1, Holubowicz *et al.*, 2014). The settings: G1 output, P1 programme and M1 mode were used. The dry seeds of the cultivars were subjected to the LFMF treatment for 10, 30, and 60 minutes, respectively, at the LFMF strength of 20 mT. The check seeds were dry and untreated. The germination test conditions followed the rules of the International Seed Testing Association (ISTA) except that they were carried out under suboptimal temperature of 15 °C (Anonymous, 2012). The first routine normal seedlings count was done after 4 days, and the second one - after 10 days. Then, additionally, all seedlings lengths and fresh weights of each treatment were measured.

For statistical analysis, the significant differences were calculated based on the Duncan's test for $\alpha=0.05$ for each seed trait. The means with significant differences were marked with different letters for morphological seed traits. For some data, standard deviation values were also calculated.



Figure 1. Viofor JPS Deluxe with the radish seeds

Results

For the seeds of the cultivar ‘Carmen’, compared with untreated seeds (CK), there was higher germination rate (energy) recorded for LFMF treatment. In the other two treatments, no differences were found (Table 1). When it came to germination capacity at stressful conditions, no differences were shown.

Table 1. Effect of treating dry radish ‘Carmen’ (C) seeds with low frequency magnetic field (LFMF) on their germination at 15 °C

Treatment	First count (%)	Final count (%)	Abnormal seedlings (%)	Hard seeds (%)	Dead seeds (%)	Fresh seeds (%)
CK	57.5 a*	97 a	3.0 a	0.0	0.0	0.0
10 min.	95.5 b	97.5 a	2.5 a	0.0	0.0	0.0
30 min.	93.5 b	95.5 a	4.5 a	0.0	0.0	0.0
60 min.	99.0 c	99.0 a	1.0 a	0.0	0.0	0.0

*Means for a given trait followed by the same letters are not significantly different according to the Duncan’s test for $\alpha=0.05$. CK – check seeds

For the seeds of the cultivar ‘Szkarłatna z Białym Końcem’, compared with untreated seeds (CK), there were higher germination rates (energy) recorded for them for all three treatments with LFMF (Table 2, Figure 2). The third of them (60 min) was better than the second one (30 min). When it came to germination capacity at stressful conditions, no differences were shown.

Table 2. Effect of treating dry radish ‘Szkarłatna z Białym Końcem’ (SBK) seeds with the low frequency magnetic field (LFMF) on their germination at 15 °C

Treatment	First count (%)	Final count (%)	Abnormal seedling (%)	Hard seeds (%)	Dead seeds (%)	Fresh seeds (%)
CK	49.5 a*	97.0 a	3.0 a	0.0	0.0	0.0
10 min	98.0 bc	98.0 a	2.0 a	0.0	0.0	0.0
30 min	96.0 b	97.0 a	3.0 a	0.0	0.0	0.0
60 min	99.0 c	99.0 a	1.0 a	0.0	0.0	0.0

*Means for a given trait followed by the same letters are not significantly different according to the Duncan’s test for $\alpha=0.05$. CK – check seeds



Figure 2. Effect of treating dry radish ‘Szkarlätna z Białym Końcem’ (SKB) seeds with low frequency magnetic field (LFMF) on their germination rate at 15 °C. CK - check seeds (untreated), 10 min - 10 minutes long LFMF seeds treatment, 30 min - 30 minutes long LFMF seeds treatment, 60 min - 60 minutes long seeds treatment. At the last 2 treatments (30 and 60 min), longer seed radicles are clearly seen

For the seedlings’ length, the seeds of the cultivar ‘C’ showed no differences between control and LFMF treatments. The treated seeds of the cultivar ‘SBK’ had all longer seedling length than that of untreated ones, and between 3 exposing time, 30 min treatment showed the best effect, while it has no difference between 30 min and 60 min (Table 3, Figure 2).

Table 3. Effect of treating dry seeds of two radish cultivars ‘Carmen’ (C) and ‘Szkarlätna z Białym Końcem’ (SBK) with low frequency magnetic field (LFMF) on the total length of the received seedlings after completing their germination at 15 °C

Treatment	Seedling length (cm)	
	C	SBK
CK	5.66 a*	4.22 a
10 min	5.89 a	5.51 b
30 min	6.74 a	6.67 c
60 min	6.72 a	6.48 bc

*Means for a given cultivar followed by the same letters are not significantly different according to the Duncan’s test for $\alpha=0.05$. CK - check, C - Carmen, SBK - Szkarlätna z Białym Końcem

For the 50 radish seedlings total fresh weight, for both cultivars, only 30- and 60-minutes treatments showed significantly higher weight than that of untreated ones. Moreover, there were no significant differences between 30- and 60-minutes treatments for both cultivars (Table 4).

Table 4. Effect of treating dry seeds of two radish cultivars 'Carmen' (C) and 'Szkarłatna z Białym Końcem' (SBK) with the low frequency magnetic field (LFMF) on the total 50 seedlings fresh weight of the received seedlings after completing their germination at 15 °C

Treatment	Total 50 seedlings fresh weight (g)	
	C	SBK
CK	2.5949 a*	1.9870 a
10 min	2.6097 a	2.1581 ab
30 min	3.1463 b	2.5317 bc
60 min	3.2045 b	2.8774 c

* Means for a given cultivar followed by the same letters are not significantly different according to the Duncan's test for $\alpha=0.05$. CK - check, C - 'Carmen', SBK - 'Szkarłatna z Białym Końcem'

Discussion

Although no differences were found in germination capacities of the seeds of both cultivars, the experiment results showed that the LFMF treatment had a positive effect on radish seed energy as well as seedlings' length and fresh weight. It was then very similar to the results reported for priming of radish seeds (Li, 2010; Maroufi *et al.*, 2011; Song *et al.*, 2015). In the selected exposing times, the effect of the LFMF treatment on radish seed germination rate (energy) of both cultivars increased with the increase of the MF exposing time. This observation has got a strong back up from literature based on the results of the experiments done on many different agricultural crops, onion and tomato (Xie *et al.*, 2007; Chen *et al.*, 2008; Xu and Zheng, 2009; Zheng and Xu, 2010; Wang *et al.*, 2011; Xie and Wu, 2011; Yuan *et al.*, 2015; He and Jian, 2016; Yuan *et al.*, 2016). Much less is though known about the magnetic treatment mechanisms to promote seed germination. Reportedly, they are related to enhancing enzymes activity in seed, accelerating seed water absorption process, stimulating protein synthesis in seeds, and promoting seed respiration (Xu and Zheng, 2009; Yao and Shen, 2015).

The results showed that the seedling length of cultivar C was not affected by the LFMF treatment, while the cultivar SBK showed positive feedback. However, there was no difference between the results of SBK for 30 and 60 minutes.

The results of total 50 seedlings' fresh weight showed that although the results of 30 and 60 minutes LFMF seeds treatments were improved compared to the check plants, still there was no difference between these two exposing times.

Extensive literature confirmed that for the different plant species and cultivars seeds, different MF treatment intensity and exposing time for positive reaction have been reported, and thereby it was possible of them to get the optimum range of values. This positive effect, reportedly, got weaker when exceeding the optimal treatment range, even when for some species, exceeding it meant a negative reaction (Zhou *et al.*, 2008; Sun *et al.*, 2010; Qi *et al.*, 2015; Ren *et al.*, 2015; He and Jian, 2016). The observation is also consistent with the results of this experiment. From this, it can be concluded that for the promotion of MF treatment in seed priming method, a large number of screening experiments for specific crops and cultivars is still needed to determine the optimal MF intensity and exposing time.

Based on the overall results of seed energy, seedling length and fresh weight of this experiment, we can conclude that the LFMF improved the radish seed quality of both cultivars 'C' and 'SBK', and 60 minutes was the most effective treatment out of the three exposing times used in the experiment.

Conclusions

The used in the experiment LFMF had a positive effect on radish seed energy as well as seedlings' length and fresh weight. It was then very similar to the results reported for priming of radish seeds.

Out of three used LFMF exposing times, the best results were received for 60 minutes treatment.

The optimal MF treatment intensity and exposing time for other radish cultivars need further research.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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