PROCEEDINGS OF THE YEREVAN STATE UNIVERSITY

Chemistry and Biology 2018, **52**(2), p. 110–115

Biology

THE INFLUENCE OF LOW-INTENSITY EMI TREATMENT ON SEED GERMINATION AND EARLY GROWTH OF WHEAT

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This study investigated the effect of pre-sowing seed treatment with low intensity EHF EMI (64 mWt/cm^2, 51.8 *GHz*) on seed germination and seedling performance of wheat (*Triticum aestivum* L.). The effects of different time of EMI-exposure (3, 5 and 10 *min*) on germination of treated wheat seeds were studied. We found that 5 min EMI treatment could significantly improve germination potential (by 7.0%) and germination rate (by 8.0%) compared with control group. At the same time, shoot height (by 10%) and fresh weight (by 12%) were improved significantly at seedling stage. However, the decrease in germination rate of longer (10 *min*) treatment groups was observed.

Keywords: *Triticum aestivum* L., EHF EMI, germination rate, shoot height, fresh weight.

Introduction. In the past few decades human's natural environment has changed, because of the brood spectrum and EMF in expanding. Daily applications of the fields in many therapeutics, transports and wireless communication of the industrial areas cause the organisms exposed to higher levels of magnetic and EMF [1, 2]. So, the problem of electromagnetic safety of organisms assumes big importance.

Plants normally grow on the land affected by EMF, because Earth acts like a magnet [3]. As a matter of fact, the natural low-intensity EMF of the Earth is a constant part of the biosphere and many processes of cell normal metabolism are associated with these natural fields [2].

Wheat (*Triticum aestivum* L.), a crop plant of Poaceae family, is one of highly demanded major yield crops in the word. It is a staple food source of more than five billion people over the world. According to the United Nations Food and Agriculture Organization (FAO), world grain production was about 2 216 billion ton, while the consumption reached 2 254 billion ton in 2012 [4]. Therefore, food security of the world has become the most severe problem of modern agriculture industry. The traditional method to improve crop yield is to improve the fertilization and irrigation, but their effects are not sustainable.

Favorable results were obtained applying millimeter waves (MWs) and microwaves in agriculture biotechnologies over the past 30 years [5, 6]. Experiments

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conducted have shown that EMI EHF (range from 30–300 *GHz*) due to its high frequency and short wavelength (from 1–10 *mm*) may interact with biosystems of different levels of organization [2, 7].

The propagation of wheat generally occurs through seed and seedling, while germination is a crucial stage in the life cycle of the plant. This process depends on the seed structure and environmental factors that affect the growth potential of the embryo [8, 9].

Researchers with the study on changes in live systems, which exposed to EMF with different intensities and exposure period, have shown the influence of EMI on the various characteristics of plants such as germination rate, root and seedling growth and even the yield of crops [10–12].

Aladjadjiyan [13] reported an increase in germination of *Gleditsia triacanthos, Caragana araborescens* and *Laburum anagyroides* seeds under microwave EMI treatment. Ragha et al. [14] proved that a certain level of microwave power and exposure time can improve the germination and seedling vigor of wheat, Bengal gram, green gram and moth bean, while a further increase in EMI frequency and power density caused a reduce in seed germination and seedling vigor of the plants. Recently, Sidorenko et al. [15] using magnetic field (40–50 *T*, 1–10 *Hz*) for the pre-germination treatment of wheat dry seeds for 1 *h*, have obtained positive results on seed germination, growing and yielding capacity parameters, as well as growing season length. Therefore, electromagnetic field, as non-chemical, non-invasive and environmentally safe external stimulant, is used for seeds pre-germination treatment in farming [16].

Due to this issue, the present study was aimed to investigate the effects of 51.8 *GHz* frequency EMI on the germination of wheat imbibed seeds considering the germination power and rate, as well as primary shoot length and fresh weight.

Materials and Methods.

Seed Material and Electromagnetic Irradiation Procedure. Seeds of wheat (*Triticum aestivum* L.) of "Bezostaya" varieties were taken for the experiment. Seeds of the same shape, color and size are selected. Before experiment the seeds with distilled water were washed, they were disinfected with 0.03% potassium permanganate ($KMnO_4$) solution for 2 *min* and thoroughly rinsed with distilled water. Then these seeds were imbibed in water for 12 *h*, 50 seeds in each Petri dish were soaked (10 *mL* of distilled water was added), in this stage white Whatman filter paper was used as the seedbed. The seeds in Petri dishes were once subjected to different (3, 5 and 10 *min*) exposure times of 51.8 GHz frequency EMI and then cultured in growth chamber, in the dark at 22±1°*C* for 7 days [17].

The irradiation was performed using the generator G4-141 type with working interval of 37.50–53.57 *GHz* (State Scientific-Production Enterprise "Istok", Russia) and power flux density 0.6 $mW{\cdot}cm^{-2}$. Frequency signal stability was ±0.05 and frequency deviation of output signal in persistent regime of generator did not exceed 6 *MHz*. The distance from the radiating end of the conical antenna to the object of irradiation was 20 *cm*. The choice of applied frequency was conditioned by the fact that water resonant and near them frequencies are in this range [7].

At the end of the experimental period the temperature of the water inside the Petri dishes around the seeds was measured. The temperature was kept constant during the EMI-exposure near the irradiating samples and was equal to 22.0±1.0°*C*.

The following EMI treatments (T) were performed: T_0 = reference (control), seeds were not affected by artificial EMI; seeds were exposed to EMI (0.6 $mW{\cdot}cm^{-2}$, 51.8 GHz) for 3, 5, 10 min: T_3, T_5, T_{10} respectively.

The effect of EMI exposure time on wheat seeds germination potential, germination rate, and germination index was investigated. Counting the germinated seeds started from the 3rd day after soaking. The standard to determine seed germination was checked when the germ length reached half of the seed length [18]. 10 plants were selected randomly and analyzed for plant height and fresh weight. There were three repeats for both the treated and control groups, respectively.

Germination indexes (G_i) were calculated according to these equations [18]:

$$G_i = \sum \frac{G_t}{D_t},$$

where G_t is the number of germinated seeds at t day; D_t is germination day:

$$\text{Germination potential (\%)} = \frac{3^{\text{rd}} \text{ day number of germinated seeds}}{\text{total seed number for testing}} \times 100,$$

$$\text{Germination rate (\%)} = \frac{7^{\text{th}} \text{ day number of germinated seeds}}{\text{total seed number for testing}} \times 100.$$

All experiments were performed in triplicate and values presented here are the mean of three values ± standard error.

Results and Discussion.

Seed Germination. The effect of EHF EMI exposure on seed germination varied with the duration of treatment (Tab. 1). The average of germination was investigated under priming, a stage preceding germination wherein the seed imbibed water and synthesized necessary proteins.

Table 1

Effect of 51.8 GHz EMI treatment on wheat seed germination

Treatment	Germination potential, %	Germination rate, %	Germination index
Control, T_0	72.6 ± 3.4	82.7± 2.8	24.2 ± 1.8
T_3	75.5 ± 2.9	86.8 ± 2.6**	24.5 ± 1.7
T_5	78.1 ± 3.0*	89.3 ± 3.2*	25.2 ± 1.2
T_{10}	73.2 ± 3.2	84.0 ± 2.6	23.8 ± 1.8

Note: the data were expressed as the mean ± standard deviation (SD); * $p < 0.05$; ** $p < 0.02$.

In this experiment, seed germination was found to increase significantly when exposed by 51.8 GHz EMI (Tab. 1). Putting different exposure times (3, 5 and 10 min) of EHF EMI to use prior to seed germination significantly accelerated the germination of the wheat seeds. The control seeds successfully germinated with a rate between 72.6–82.7%. Thus, 72.6% of the seeds germinated after 3 days, and this percentage was even increased up to 82.7% after 7 days (Tab. 1).

As it is obvious from the data represented in Tab. 1, the EMI treatment in 3 and 5 min further stimulates seed germination of wheat. Thus, 3 and 5 min EMI treatment could significantly increase germination potential (by 4 and 7% respectively) and germination rate (by 5 and 8% respectively) in comparison with control. But with the increasing influence time-up to 10 *min*, the germination tests revealed no significant differences of studied traits as compared with control. Note that germination index of all treatments had no significant differences compared with control.

Plant Growth. EHF EMI affected the plant growth after treating the pre-sowing seeds with considerable changes in shoot height and fresh weight (Tab. 2). The short time (3 *min*) EMI-treatment did not induce changes in studied morphometric traits either for 4- and 7-days old plants.

On the 4th day of growing the shoot height and fresh weight of seedlings from both (5 and 10 *min*) pre-treated groups were significantly higher in comparison with control (Tab. 2).

Table 2

Effect of 51.8 GHz EMI treatment on the growth of wheat

Growth day	Treatment	Shoot height, *mm*	Shoot fresh weight, *mg*
4th	T_0	47.2 ± 1.3	45.4 ± 1.4
	T_3	48.1 ± 2.0	47.2 ± 1.3
	T_5	52.2 ± 2.4*	50.8 ± 2.1*
	T_{10}	50.9 ± 1.8*	49.5 ± 1.7*
7th	T_0	61.4 ± 1.9	58.3 ± 0.8
	T_3	63.2 ± 2.1	60.6 ± 1.2
	T_5	64.5 ± 2.3**	61.4 ± 1.4**
	T_{10}	63.8 ± 1.7	61.2 ± 1.4**

Note: the data were expressed as the mean ± standard deviation (SD): * $p < 0.05$; ** $p < 0.02$.

The plant grown from EMI (5 and 10 *min*) treated pre-sowing seeds had considerably larger shoot height (by 10 and 8.2% respectively) as compared with control. In addition, fresh weights of the same group treated plans were significantly higher than that of the control by 12 and 9.1%.

Surprisingly, those results were not maintained on the 7th day of growing, when the total fresh weights were almost similar for the both experimental and control plants, and were not significantly different (58.3, 61.4 and 61.2 *mg* for the T_0, T_5 and T_{10} respectively).

Seed dormancy is an innate seed property that enables the species to reproduce generatively to survive [8, 9]. EHF EMI are considered as a stimulation treatment to break down seed dormancy and to increase the germination traits [5]. There is a large body of experimental data demonstrating various effects of EMF on seed germination, plants growth and development. Although the mechanism(s) of perception of EMF by plants is not yet elucidated well, there is a possibility that like other stimuli, ENF exerts its effects on plants by changing membrane integrity and conductance of its water channels, thereby influencing the growth traits [2, 7].

The results of previous studies on effects of EHF EMI on seed germination indexes are also still contradictory. According to our results, exposing the imbibed seeds to 5 *min* EMI on the first day of soaking was very important in improving the seed germination percentage and rate. Our data matched well with the findings of Mazets [19] in *Lupinus* seeds and Zare [20] in *Zea mays* seeds. On the other hand, Kalie [21] reported a significant delay in germination rate of barley seeds treated by EMI of 64.5 *GHz* frequency in 5, 10 and 15 *min*.

The results obtained in our study showed that the treated wheat seedlings had longer steam and are heavier therefore they will be better at absorbing water and nutrition. This work conformed the existence of relationship between pre-treatment exposure time and direction of physiological response of the plant, and is in accordance with data from [22], where 5 *min* exposure of purple coneflower to EMF increased the weight and germination rate, while two-times longer exposure decreased them.

Conclusion. In this study we revealed that EMI treatment with 51.8 *GHz* frequency could improve the germination and promote the growth of wheat. In 5 *min* period of germination rate increase rather to the control group, but further shifting the effective time to 10 *min*, the growth decreased to some extent. Further research is needed to a better understanding of the specific role of EMI-treatment in promoting the growth of wheat.

Received 23.01.2018

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