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EFFECT OF EXTREMELY HIGH FREQUENCY ELECTROMAGNETIC IRRADIATION TREATMENT ON GERMINATION, GROWTH AND AMYLASE ACTIVITY OF WHEAT SEEDS

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In this work, the effect of low-intensity (non-thermal, flux capacity 0.06 mW/cm^2) electromagnetic irradiation (EMI) of extremely high frequency (EHF) (42.2 *GHz* and 50.3 *GHz*) as pre-sowing treatment on germination, early growth and α-amylase activity of wheat seeds (*Triticum aestivum* L.) has been studied. The measurements conducted during seed germination were the germination energy and germination power, germination index, shoot and root length, as well as fresh weight. The laboratory experiment followed a completely randomized design, with four treatments (control, 5 *min* – T5, 10 *min* – T10, and 15 *min* – T15) and three replications. It was shown that EHF EMI pre-sowing treatment at both used frequencies favored the germination and growth of wheat seeds, and results were more expressed at a frequency of 50.3 *GHz* – the resonant frequency of water. We found that EMI with 50.3 *GHz* for 10 *min* significantly improved germination energy (by 6.5%) and germination power (by 7.6%). At the same time, shoot high (by 11%), root length (by 12%) and fresh weight (15%) were enhanced significantly at seedling stage compared with the control. Furthermore, the measured activity of α-amylase reviled that EMI-treatment increased the enzyme activity more than 2-fold, thereby probably promoting wheat germination.

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Keywords: electromagnetic irradiation of extremely high frequency, wheat treatment, seed germination, seedling growth, α-amylase activity.

Introduction. Extremely high frequency (EHF) electromagnetic irradiation (EMI) (a range from 30 *GHz* to 300 *GHz*) or low-intensity millimeter waves (MMW) is a constant part of a biosphere and intensively influences living organisms [1, 2]. Nowadays, MMW technologies are increasingly being used in wireless communication, traffic and military radar systems, which makes the investigation of EHF irradiation influence on living matter very important [3].

Plants normally grow on the land affected by electromagnetic and magnetic fields (EMF), and many processes of cell normal metabolism are associates with these natural fields [1, 4]. Plants are essential components of a healthy ecosystem and have important role in the living world as main primary producers of food and

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oxygen, therefore, it would be beneficial to investigate their interaction with today's increased exposure to radio and millimeter frequency fields.

Wheat (*Triticum aestivum* L.), a crop plant of Poaceae family, is the leading grain crop in the world with a production of 750.1 million tons in 2017–2018 [5]. It is a staple food source of more than five billion people across the world [6]. Cereal crops form the basis of agricultural production. They are the most common and the most valuable in the world among all field crops.

The increasing demands of food and other industrial sectors for improved corn yield has led the farming to new challenges. The traditional method to improve crop yield is to improve the irradiation and fertilization, but their effects are not sustainable.

One of the obligatory elements of the technological preparation of cultivating cereal crops, which affects crop production yield and quality, is the pre-sowing treatment seeds with physical (UV-rays, hot water, sunlight) or chemical (antibiotics, pesticides) methods [7, 8]. But the last one could bring ecological risk worldwide. Nowadays, in farming there is a growing interest in applying alternative environmentally-friendly methods such as pre-sowing seed microwave treatment [7–12] and the application of cold plasma technology [13, 14].

Electromagnetic fields are widely used to stimulate germination of seeds, improve their quality and speed up to growth of plants, over the past 30 years [7–9, 12]. At present the ability of simultaneously generating the effects of biostimulation, disinfection and disinsectization during irradiation of seeds from different agricultural plants by electromagnetic waves of MM range has been discovered and experimentally proved [7, 8, 12, 15]. Seeds treatment by MMW and microwaves is an innovative approach resulting in improved germination and plant growth. Many studies have conformed the potential of EMF pre-treatment on germination, early growth and even the yield of wheat seeds [7, 9, 11, 16, 17], rice seeds [10], barley seeds [9, 18], maize seeds [19], and other crops.

Thus, Regha at al. [20] 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. Talei at al. [10] have demonstrated that 2450 *MHz* microwave frequency pre-sowing treatment from 1–10 *h* of rice seeds could significantly improve the germination percentage and rate, as well as primary shoot and root length. Recently, Bezpalko at al. have highlighted the positive impact of EMI (2.5–3.4 *GHz* at the power of 0.9–1.8 *kW*/*kg* during 5–95 *s*) pre-sowing treatment of wheat and spring barley seeds on sprouting energy and germination power [9].

The data showed that EMF-treatment also influence the physiological activities of seeds such as biochemical composition and activity of hydrolytic enzymes-amylases [11, 18, 19].

Mazets et al. [21], using EHF EMI (regimes: 20 *min* – 53.57 *GHz*, 12 *min* – 64.0–66.0 *GHz*, and 8 *min* – 64.0–66.0 *GHz*) for the pre-germination treatment of *Lupinus angustifolius* L. seeds, reported an enhancement in α-amylase activity, shoot high and fresh weight depending on EMF treatment frequency used. EMF treatment of MMW range has been found to increase the activity of hydrolytic and proteolytic enzymes such as amylases and proteinases in barley seeds [18]. The results obtained in [11] testify an increase in chlorophyll content, photosynthetic and transpiration rate, as well as α-amylase activity in pulsed EMF pre-treated durum wheat seeds.

α-Amylase (1-4-α-D-glucanglucanohydrolase EC 3.2.1.1) catalyzes endo-hydrolysis of 1-4-α-glucosidic linkages in starch and any related oligosaccharides to make oligosaccharides and glucose. In plants, α-amylase plays a key role in starch degradation during seed germination [22, 23].

The increase of enzyme activity could be a primary positive effect of MMW field treatment that subsequently leads to higher germination and plant growth.

Obtained results indicate that effects of EMF on alive systems are strongly connected with EMI intensity, exposure duration and especially EMI frequency applied. However, the specific mechanisms of EMI EHF action on biological systems remained not clear yet. A few mechanisms of EMI interaction with living organisms are discussed [1, 24].

It is important to note that these effects are the result of exposure to EMF of very low intensity (less than 10 mW/cm^2) have the frequency dependence of the resonant nature and are characterized by intensity thresholds, at which the effect begins to show jump like manner [1, 24].

To the best of our knowledge, the results of previous studies on the effects of EHF EMI on seeds germination and early growth trails are still contradictory.

Due to this issue, the present study was aimed to investigate the effects of 42.2 and 50.3 *GHz* frequencies EMI on the germination of wheat imbibed seeds considering the germination energy and power, as well as shoot and roots length and fresh weight. The α-amylase activity was also investigated to explain the germination changes of sprouting seeds.

Materials and Methods.

Seed Material. For this study, conditioned and nonconforming wheat (*Triticim aestivum L.*), "Bezostaya" variety seeds were supplied by forest nursery "Kotayk" (Kotayk Region, Armenia) from 2019 harvesting year. Only ripe intact seeds without visible defects were selected.

Seed Preparation. The seeds were surface sterilized (70% ethanol for 1 *min* and 5% sodium hypochlorite for 5 *min*) and thoroughly rinsed in distilled water. Seeds were imbibed for 12 *h* in distilled water. Fifty seeds were then soaked in culture Petri dishes. Each culture dish was covered with two lays of filter paper (15 *mL* distilled water was added). The seeds in Petri dishes were once subjected to different (5, 10 and 15 *min*) exposure times of 42.2 and 50.3 *GHz* frequency EMI, then placed to germinate at 22±1.0°C and relative humidity 70–80% in grow-chamber for 8 days in darkness with a water supply as that described elsewhere [17]. Counting the germinated seeds was started from 3rd day after soaking. The standard to determine seed germination was checked when the germ length reached half of the seed length. The germinating energy was calculated in 3 days, and the laboratory germinating power was calculated in 7 days. Germination indexes were calculated according to these equations [25]:

$$- \ germination\ energy\ (\%) = \frac{3rd\ day\ number\ of\ germinated\ seeds}{total\ number\ for\ testing} \times 100\%;$$

- $germination\, power\ (\%) = \frac{7th\ day\ number\ of\ germinated\ seeds}{total\ number\ for\ testing} \times 100\%$;
- $germination\ index\ G_i = \sum \frac{G_t}{D_t}$, where G_t is the number of germinated seeds at *t* day, D_t is the germination day;
- 10 plants were selected randomly and analyzed for plant high, root length and fresh weight.

The experiment had a completely randomized design (CRD) with four (three different exposure times of 42.2 and 50.3 *GHz* frequencies and control) treatments and three replications. EHF EMI-treatment was applied for 5, 10, 15 *min*. The treatments were included as C (control), T5 (5 *min*), T10 (10 *min*), and T15 (15 *min*). Seeds that were not treated were used as control.

Exposure of Seeds to Electromagnetic Irradiation. Wet, 12 *h* imbibed seeds soaked in Petri dishes were irradiated with coherent electromagnetic waves of 42.2 and 50.3 *GHz* frequencies using a generator of G4-142 type (State Scientific Production Enterprise (SSPE) "Istok", Fryazino, Moscow Region, Russia). The frequency stability of generator in continuous wave mode was up to 20 *MHz*; the amplitude-modulation frequency was 1 *Hz*. The distance from the radiating end of horn antenna to the object of irradiation was 20 *cm*. For this distance, the power flux density measured using a M5-45 thermistor head and a M3-10A wattmeter (SSPE "Istok") was 0.064 mW/cm^2. The frequency output signal was controlled by a CH-25 wavemeter (SSPE "Istok"). The horn antenna with diagonal of 24 *mm* and altitude of 34 *cm* provided equal distribution power to the exposed sample in mentioned distance. Specific absorption rate (SAR) of generator was less than 4 *W/kg*, which does not invoke thermal effects.

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

Amylase Activity Assays. α-Amylase activity was determined according to the method of Jones and Varner [26]. Seeds were extracted in 0.2 *M* citrate buffer (pH 5.5), centrifuged at 8000 *g* and the supernatant was used for enzyme assay. 0.2 *mL* of enzyme extract was diluted to make the volume 1.0 *mL* with distilled water. The reaction was started by the addition of 1.0 *mL* of starch substrate for 1 *h*. The starch substrate was prepared by the addition of 150 *mg* potato starch in 100 *mL* of solution containing 600 *mg* KH_2PO_4 and 200 *μmol* $CaCl_2$. The mixture was boiled for 1 *min*, centrifuged for 10 *min* at 3000 *g* and clear supernatant was used as the substrate. The reaction was stopped by the addition of 1 *mL* of iodine reagent (6 *g* of KI and 600 *mg* of iodine were dissolved in 100 *mL* of water, before use 1.0 *mL* of the stock solution was added to 0.05 *N* HCl and made the volume to 100 *mL*). To this reaction mixture, 5.0 *mL* of distilled water was added, mixed and measured the absorption at 620 *nm*. The α-amylase activity was calculated as the amount of starch hydrolyzed per minute per mg of protein. Protein content was determined according to the method of Lowry [27] with bovine serum albumin as a standard.

For assessing the protein content and α-amylase activity UV-visible Spectrophotometer (mode SF-46, USSR) was used.

Statistical Analysis. For quantitative analysis results are represented as means ± standard deviation. One-way analysis of variances method was adopted for statistical analysis. A value of $p < 0.05$ indicated significance.

Results and Discussion.

Seed Germination. The effects of EMI pre-sowing treatment of wheat seeds with 42.2 and 50.3 *GHz* frequencies on seeds germination energy, germination power and germination index have been studied. For irradiation 42.2 and 50.3 *GHz* frequencies were chosen the first of which is non-resonant and the second considered as resonant frequency for water [1, 24].

Specifically, 42.2 *GHz* frequency was chosen as one of the most common frequencies such as 35.1, 53.6, 61.2 and 78 *GHz* used in different medical applications [3, 28]. The value of 42.2 *GHz* is non-resonant frequency for water as it is obvious in the statements [1, 3, 28], and this frequency was applied earlier in studies on growth and antioxidant enzymes activity in wheat [17, 29, 30].

50.3 *GHz* frequency was considered to be water resonant [1, 24]. Recently it has been shown, that MMW with frequencies 50.3, 51.8 and 65 *GHz* (wavelength 5.96, 5.79 and 4.6 *mm*) are corresponding to water cluster structure vibrations or resonant frequencies, in which the biological effects are more pronounced [1, 24]. It is supposed, that MMW of resonant frequency are capable to change the structure and properties of water component of cells, thus, to influence at the conformation of biomolecules, responsible for biochemical reactions [24, 28].

The average of germination was investigated under priming, a stage preceding germination wherein the seed imbibed water and synthesized necessary proteins.

As it is obvious from represented in Tab. 1 and Fig. 1 data, the effect of EMI on germination trails varied with treatment duration and EMI frequencies used.

Germination energy and germinating power of control seeds were 74.5% and 88.7%, respectively. They successfully germinated with a rate between 74.5–88.7%. Thus, 74.5% of the seeds germinated after 3 days, and this percentage was even increased up to 88.7% after 7 days.

Table 1

Effect of EMI seeds pre-sowing treatment on wheat seed germination

Treatment	Germination energy, %	Germination power, %	Germination index
42.2 *GHz*			
Untreated	74.5 ± 1.6	88.7 ± 2.3	20.3 ± 1.2
T5	75.6 ± 1.7 $^{n.s.}$	90.5 ± 2.5 $^{n.s.}$	21.4 ± 0.6 $^{n.s.}$
T10	76.7 ± 1.7 $^{n.s.}$	94.1 ± 2.8*	20.4 ± 0.8 $^{n.s.}$
T15	77.2 ± 2.0 $^{n.s.}$	91.0 ± 1.6 $^{n.s.}$	22.1 ± 1.3 $^{n.s.}$
50.3 *GHz*			
Untreated	74.5 ± 1.6	88.7 ± 2.3	20.3 ± 1.2
T5	76.1 ± 1.8 $^{n.s.}$	91.6 ± 2.6 $^{n.s.}$	20.8 ± 1.1 $^{n.s.}$
T10	79.4 ± 2.2*	95.4 ± 3.1**	21.6 ± 1.7 $^{n.s.}$
T15	75.2 ± 1.6 $^{n.s.}$	89.2 ± 2.4 $^{n.s.}$	21.3 ± 1.6 $^{n.s.}$

Note: Mean value of three replicates ± standard deviation. p-Significance by LSD atp from control, $^{*}p < 0.05$, $^{**}p < 0.002$, n.s. – not significant.

For the EMI pre-sowing treatment with 42.2 *GHz* statistical analysis showed not significant differences compared to control (Tab. 1). Only in case of 10 *min* exposure duration germination power increased by 6.1% and reached 94.1±2.8%.

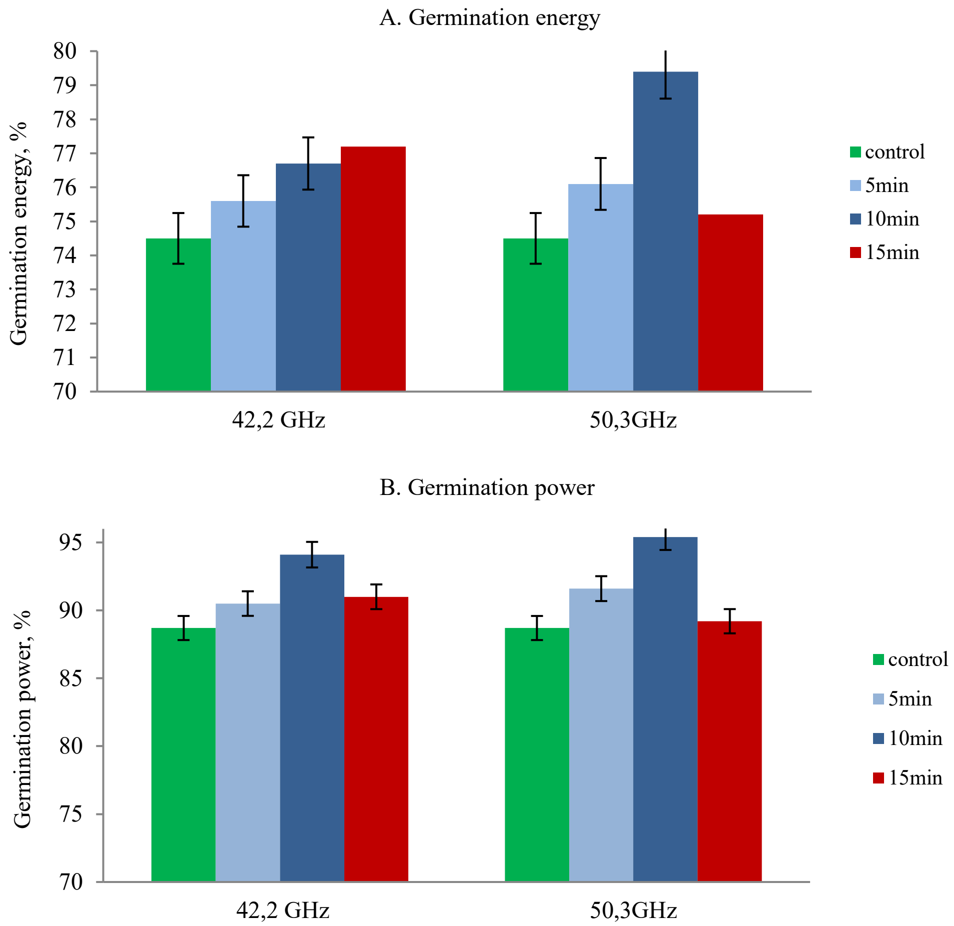

Fig. 1. Germination energy (A) and germination power (B) of wheat seeds after irradiation with EMI of 42.2 *GHz* and 50.3 *GHz* frequencies at different exposure times.

Similar but more pronounced effect noticed in the case of 50.3 *GHz* EMI seeds pre-treatment (Tab. 1, Fig. 1). As it is obvious from Tab. 1, the use of 5 *min* pre-sowing treatment of wheat seeds did not provoke statistically significant changes in germination characteristics, which were practically the same as that for control. In the case of 2-fold longer exposure duration – seeds 50.3 *GHz* pre-sowing treatment for 10 *min*, significantly enhanced the laboratory germination energy and germination power by 6.5% and 7.6% in comparison with control. The highest values of studied trails were observed at the exposure 10 *min* duration (Tab. 1). Surprisingly, the further increase of seed irradiation time up to 15 *min* resulted in a significant decrease in germination energy and germination power by 5.4% and

6.6% compared to 10 *min* exposure values, and these parameters became almost the same as for control ones.

It is necessary to note that germination index of all treatment had no significant differences compared with control (Tab. 1).

So, as it is obvious from obtained data (Tab. 1, Fig. 1), the greater response of germination, which expressed by germination power increasing was recognized in case of wheat seeds EMI pretreatment by 50.3 *GHz* frequency for 10 *min*. Seemingly, this fact indicates that the biological effect of MMW EMI on organism level is performed at water resonant frequencies that show the certain role of water in biosystems response creation [1, 24, 28].

It is well known, that the high germinating energy characterizes the ability of seeds to germ quickly and all at once. The healthy seed aligned with the physiological stat, has this property. Fast and even germination of seeds indicates that seedlings will be strong and resistant to unfavorable environmental conditions during the sowing and germination [22, 31].

Seed dormancy is an innate seed property that enables the species to reproduce generatively to survive [25]. EHF EMI of low, non-thermal intensity is considered as a stimulation treatment to break down seed dormancy and to improve germination trails [7–9, 15]. There is a large body of experimental data demonstrating various effects of EMFs on seed germination, plants growth and development [8–10, 13, 16–18, 20].

Also, the results of previous studies on the effects of EHF EMI seeds pretreatment on seeds germination trails are still contradictory. According to our results, exposing the imbibed seeds to 10 *min* EMI on the first day of soaking was very important in improving the seed germination percentage and germination energy. Our data coincided well with the findings of Bezpalko [9] in wheat and barley seeds and Talei at al. [10] in rice seeds. On the other hand, Kalie [18] showed a significant delay in germination trails of barley dry seeds treated by EMI of 64.5 *GHz* frequency in 5, 10 and 15 *min*.

Plant Growth. EHF EMI affected the plant growth after treating the pre-sowing seeds with considerable changes in shoot high, root length and fresh weight (Tab. 2).

As it is obvious from the presented data, the EMI-treatment for both EMI frequencies used gives statistically significant differences for studied growth characteristics.

In particular, 42.2 *GHz* pre-sowing treatment of wheat seeds for 10 and 15 *min* results in shoot high and root length higher values (by 6 and 7%, and by 8.1 and 6.2%, respectively) compared to non-treated samples. In addition, fresh weights of treated seedlings for the same exposure periods (10 and 15 *min*) were significantly higher than that of the control by 12% and 11% (Tab. 2).

In 50.3 *GHz* exposure seeds the increase of growing indexes was more expressed than in those treated by 42.2 *GHz* EMI for all irradiation periods. Thus, shoot high, root length and fresh weight of seedlings derived from 50.3 *GHz* 10 *min* treated seeds were 77.2 *mm*, 87.3 *mm* and 4.92 *g*, significantly increased by 11, 12 and 15%, respectively, as compared with control (Tab. 2). The same trend regularity was observed for 15 *min* EMI treatment. Furthermore, treating seeds with 50.3 *GHz* water resonant frequency for 10 *min* could facilitate and improve the germination indices (primary shoot and root length, fresh weight) in a significant manner.

Our results matched well with the data cited in literature. Increased shoots length and weight in winter wheat (*Treaticum aestivum* L.), barley (*Horderum vulgare* L.) and moth bean (*Vigna aconitifolia* L.) plants subjected to EMI have been reported [17, 18, 20]. The result of present study are in good conformity with these data.

Also, Morozov and Blokhin [8] in a winter wheat "Kazan 560" variety laboratory and field experiment found that the treatment of EMF of 72 *GHz* for 20 *min* increased seedlings high and root length by 2,6- and 1,5-fold, compared to control. Talei at al. [10] concluded that by applying microwave treatment (2450 *MHz* 10 *h* for 6 days) the shoot and root length of rice seedlings could be improved. Payes and Ghanati [16] reported that 10 *KHz* EMF-treatment (for 4 days each 5 *h*) of wheat seeds significantly reduced seedling length and subsequent vigor index I. Their findings are just the opposite to our results.

In the present study, we observed that the plant high, root length and fresh weight of wheat seedlings derived from EHF EMI treated seeds were significantly improved at seedling stage. Compared to the control, the treated seedlings had longer root, bigger high and heavier weight, therefore they will be better at absorbing water and nutrition, and could get more sunshine for photosynthesis.

Table 2

Effect of EHF EMI seeds pre-treatment on the growth of wheat 8-days old seedlings derived from treated seeds

Treatment	Shoot high, *mm*	Root length, *mm*	Fresh weight, *g* per plant
42.2 *GHz*			
Untreated	68.4 ± 2.3	78.0 ± 3.2	4.28 ± 0.19
T5	71.1 ± 2.4	$81.9 \pm 2.8^{*}$	4.45 ± 0.29
T10	$72.5 \pm 2.6^{*}$	$84.2 \pm 3.4^{*}$	$4.79 \pm 0.37^{*}$
T15	$73.2 \pm 1.8^{*}$	$82.5 \pm 3.1^{*}$	$4.75 \pm 0.26^{*}$
50.3 *GHz*			
Untreated	68.4 ± 2.3	78.0 ± 3.2	4.28 ± 0.19
T5	$72.8 \pm 2.2^{*}$	$83.6 \pm 3.5^{*}$	$4.54 \pm 0.33^{*}$
T10	$77.2 \pm 2.8^{***}$	$87.3 \pm 4.0^{***}$	$4.92 \pm 0.27^{**}$
T15	$76.0 \pm 2.7^{**}$	$88.4 \pm 4.6^{***}$	$4.88 \pm 0.30^{**}$

Note: $^{*}p < 0.05$, $^{**}p < 0.002$, $^{***}p < 0.001$.

α-Amylase Activity. In this study it was found that α-amylase from germinating wheat seeds showed maximum activity after 5 days of growth and then declined rapidly during following 2 days (Fig. 2).

From this information, we decided to measure enzyme activity in EMI-treated seeds in the third, the fourth, the fifth and the sixth day after sowing (Fig. 3, A, B).

As it is obvious from obtained data (Fig. 3), EMI pre-treatment by both used frequencies increased enzyme activity, thus giving an advantage during germination. The observed effects were more expressed at EMI treatment by 50.3 *GHz* frequency, which is the water resonant frequency as it is known well [1, 24].

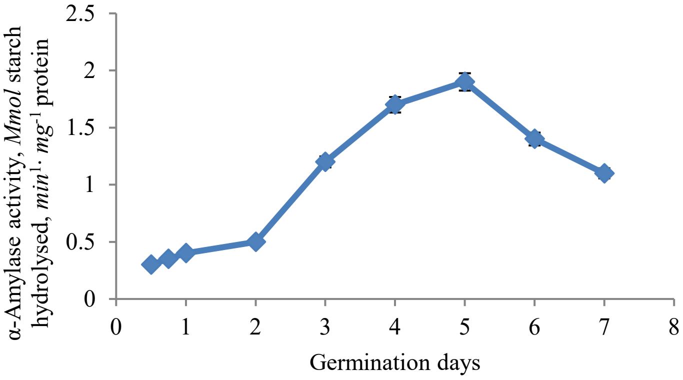

Fig. 2. Evaluation of α-amylase activity during wheat seeds germination. Each value is the average of three tests.

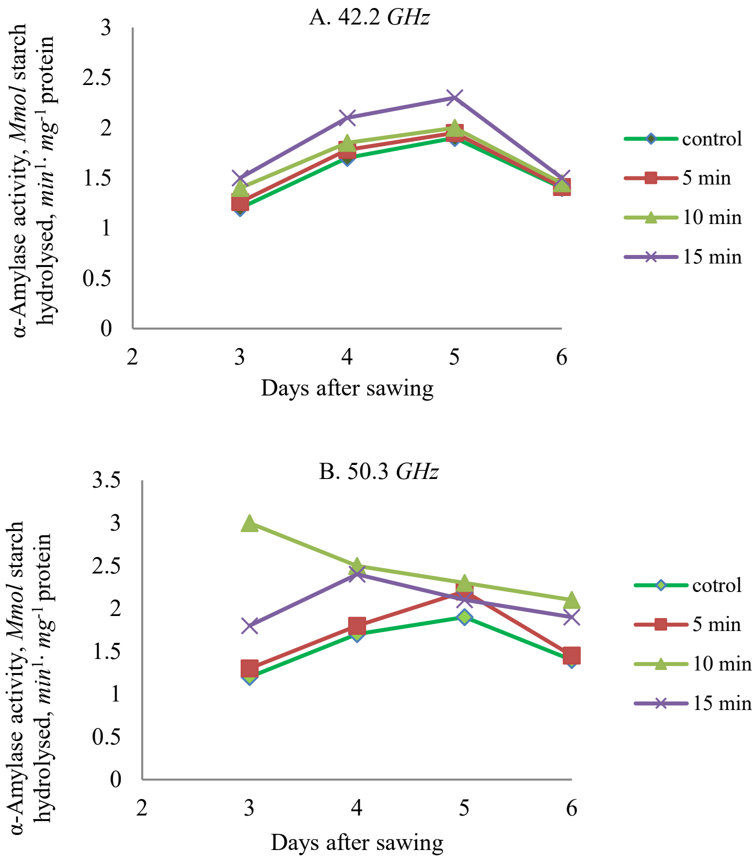

Fig. 3. Changes in the activity of α-amylase in wheat cotyledons derived from EMI-pre-sowing treated seeds with 42.2 *GHz* (A) and 50.3 *GHz* (B) frequencies.

Thus, on the 3rd day after sowing 10 and 15 *min* duration EMI treatment enhanced amylase activity by more than two fold compared whit the control treatment (Fig. 3, B). On the 4th and 5th day after seeding the EMI 10 *min* treatments resulted in an increasing activity of 115–121% compared with untreated samples.

Based on these data, we assume that most probably EMI energy by 50.3 *GHz* frequency is absorbed by embryo being mediated through water. It was proven that under EMI of MM range effect, the water structure becomes less ordered [24]. It is very likely that energy content of the used EMI frequency facilitated the movement of water molecules and perhaps increased the water absorbance by the embryo of wheat seeds, and this can be justified by the enhancement in the measured trails such as germination energy and germination power.

The germination and seedling establishment are the most critical periods of the plant life. Seed development and maturation may be viewed as a preparation to withstand these periods.

Starch, a primary product of photosynthesis in higher plants is storage carbohydrate that supports metabolism and growth during the dark when photosynthesis is not possible [25]. The enzyme most frequency credited with the initial attack on starch granules is α-amylase. This enzyme is responsible for initiating the mobilization of starch in germinating seeds [32].

In this regard of considerable interest is the study of amylase activity as a marker of the primary stress response of plant organisms to low-intensity EMI of wheat seeds. Our results matched well with the findings of Mazets et al. [21] in Lupinus seeds, where extremely low intensity EMI (range 53.57–78.33 *GHz*) pre-sowing treatment leads to more than 2-fold enhancement of α-amylase activity and seeds germination trails. Additionally, in barley dry seeds the pretreatment with MMW testify that this type of radiation has either stimulating or inhibitory effect upon germination process and amylase activity [18].

Conclusion. According to the results of the research, the pre-sowing EHF EMI treatment enhanced germination, early growth and fresh weight of wheat "Bezostaya" cultivar. Duration of 10 and 15 *min* at 50.3 *GHz* – water resonant frequency of pre-sowing treatment gave the best results. Also, the exposure of seeds to EMI was found to enhanced the activity of α-amylase in the three days following the sowing, thus giving an advantage during germination.

Based on obtained positive effects of EMI wheat seeds pre-sowing treatment on germination indices and seedling growth, this method is expected to benefit the seed germination considering its simplicity and ecological safety.

Although the mechanism(s) of perception of EMI by plants is not yet elucidated well, there is a possibility that like other stimuli, EMF exerts its effects on plants by changing membrane integrity and conductance of its water channels, thereby influencing the growth trails.

Further studies are required to investigate the mechanisms of action of EHF EMI treatment in promoting of seed germination and growth of wheat.

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ԾԲՀ-ՏԻՐՈՒՅԹԻ ԷՄՃ ԱԶԴԵՑՈՒԹՅՈՒՆԸ ՑՈՐԵՆԻ ՍԵՐՄԵՐԻ ԾԼՄԱՆ, ԱՃԻ ԵՎ ԱՄԻԼԱԶԻ ԱԿՏԻՎՈՒԹՅԱՆ ՎՐԱ

Աշխատանքում ուսումնասիրվել է ցածր ինտենսիվությամբ (հոսքի հզորության խտությունը 0,06 *մՎտ/սմ*^{2}) ծայրահեղ բարձր հաճախականության (ԾԲՀ) (42,2 *ԳՀց* և 50,3 *ԳՀց*) էլեկտրամագնիսական ճառագայթման (ԷՄՃ)՝ որպես սերմերի նախացանքային մշակման գործոնի, ազդեցությունը ցորենի (*Triticum aestivum* L.) սերմերի ծլունակության, ծիլերի աճի և α-ամիլազի ակտիվության վրա: Ուսումնասիրվել է սերմերի լաբորատոր ծլունակությունը, ծլման էներգիան և ինդեքսը, ծիլերի բարձրությունը և արմատիկի երկարությունը, ինչպես նաև ծիլերի կշիռը: Փորձը իրականացվել է լաբորատոր պայմաններում չորս տարբերակով և եռակիկրկնությամբ (ստուգիչ, ճառագայթահարմամբ՝ 5 *րոպե*՝ T5, 10 *րոպե*՝ T10 և 15 *րոպե*՝ T15):

Պարզվել է, որ ցորենի սերմերի վերաբերյալ ցուցանիշների փոփոխությունը կախված է ԾԲՀ ԷՄ ճառագայթահարման հաճախականությունից և տևողությունից: Ցույց է տրվել, որ 42,2 *ԳՀց* հաճախականությամբ ԷՄՃ ազդեցությունն ավելի թույլ է արտահայտված, քան 50,3 *ԳՀց* հաճախականության դեպքում, ինչը հաստատում է ջրի դերը ԾԲՀ ԷՄՃ ազդեցության ձևավորման գործում, քանի որ 50,3 *ԳՀց*-ը ջրի ռեզոնանսային հաճախականություններից մեկն է: Պարզվել է, որ սերմերի ճառագայթահարումը 10 *րոպե* տևողությամբ և 50,3 *ԳՀց* հաճախականությամբ մեծացնում է սերմերի ծլունակությունը և ծլարձակման էներգիան համապատասխանաբար 6,5 և 7,6%-ով: Միաժամանակ ծիլի բարձրությունը, արմատիկի երկարությունը և ծիլերի կշիռը աճում են ստուգիչի համեմատ 11, 12 և 15%-ով: Պարզվել է նաև, որ սերմերի ԷՄ ալիքներով ճառագայթահարումը բերում է հիդրոլիտիկ ֆերմենտ ամիլազի ակտիվության ավելի քան կրկնակի աճի, դրանով, հավանաբար, նպաստելով ցորենի սերմերի ծլմանը:

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ВЛИЯНИЕ ОБРАБОТКИ ЭЛЕКТРОМАГНИТНЫМ ОБЛУЧЕНИЕМ КВЧ ДИАПАЗОНА НА ПРОРАСТАНИЕ, РОСТ И АКТИВНОСТЬ АМИЛАЗЫ СЕМЯН ПШЕНИЦЫ

В работе исследовано влияние низкоинтенсивного (плотность потока мощности 0,06 *мВт/см*^{2}) электромагнитного излучения крайне высоких частот (ЭМИ КВЧ) (42,2 *ГГц* и 50,3 *ГГц*) как фактора предпосевной обработки семян пшеницы (*Triticumaestivum* L.) на их прорастание, ранний рост и активность α-амилазы. В ходе прорастания и развития проростков были исследованы лабораторная всхожесть, энергия, индекс прорастания и высота проростков, длина корней, а также сырой вес проростков. Опыты проводились в лабораторных условиях в четырех вариантах и трех повторностях (контрольный, время облучения 5 *мин* – T5, 10 *мин* – T10 и 15 *мин* – T15). Показано, что вышеотмеченные параметры семян пшеницы зависят от частоты и продолжительности облучения ЭМИ КВЧ диапазона. Показано также, что при облучении с частотой 42,2 *ГГц* воздействие ЭМИ выражено гораздо слабее, чем при облучении с частотой 50,3 *ГГц*, что подтверждает роль воды в формировании влияния ЭМИ КВЧ, поскольку частота 50,3 *ГГц* является резонансной частотой для воды. Обнаружено, что облучение семян с частотой 50,3 *ГГц* и продолжительностью 10 *мин* увеличивает всхожесть и энергию прорастания семян на 6,5 и 7,6% соответственно. Одновременно высота проростков, длина корней и сырой вес проростков увеличиваются на 11, 12 и 15% соответственно по сравнению с контролем. Далее было показано, что ЭМИ-обработка семян приводит к увеличению активности α-амилазы более чем в 2 раза, тем самым, возможно, способствуя прорастанию семян пшеницы.