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Article

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FORMATION OF THE QUALITY OF WHEAT GRAIN BY EXTREMELY LOW FREQUENCY ELECTROMAGNETIC FIELD TREATMENT

The object of the study is the treatment of wheat grain with an electromagnetic field (EMF) of extremely low frequencies (ELF), the subjects of the study are the quality indicators of wheat seed grain of the Shestopalivka variety 2019 and 2020 crops grown in the Odesa region (Ukraine). Problematic issues in the treatment of wheat grain with ELF EMF are the rationale for the duration of treatment of grain and the frequencies of EMF that improves the quality of seeds.

The studies used methods of laboratory determination of seed quality indicators, calculation of statistical characteristics of the length of sprouts, and graphical methods for interpreting the results of studies.

The studies substantiated the modes of treatment wheat grain with ELF EMF, which improves the quality of seeds and reduces the energy intensity of treatment. The effect of the duration of grain treatment and the frequency of EMF on the germination and characteristics of the length of seed shoots was studied.

It has been established that, compared with untreated grain, the treatment of grain with an EMF with a frequency of 30 Hz, a magnetic induction of 10 mT for 6 minutes increases grain germination by 2–3 %, gives longer and 1.44–1.53 times more uniformly sprouted sprouts. Treatment within 60 min. reduces up to 9 % the germination of grain, the size of the shoots, increases their unevenness in length. The effect of seed germination activation by EMF treatment increases after 19 days of storage.

Treatment of wheat grain in 2019 with ELF EMF at a frequency of 15–17 Hz with a magnetic induction of 10 mT for 6 min. changes germination within ±3 % control. The germination of the treated grain of wheat in 2020 of the crop decreases relative to the control to 13 % (with the exception of the frequency of 16.5 Hz, at which it did not change).

Thus, the treatment of wheat grain with EMF makes it possible to influence the quality of seed grain. The results obtained encourage further research with a wider range of regime parameters and areas of wheat cultivation.

Keywords: *wheat grain, electromagnetic field treatment, extremely low frequencies, germination, seed sprouts, statistical characteristics.*

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1. Introduction

In the 80s of the last century, it was found that the influence of a microwave electromagnetic field (EMF) leads to an increase in germination, an increase in the biomass of the final product. Odessa scientists proposed a hypothesis explaining this effect [1].

The same scientists, in a group of representatives from several institutions, conducted a study of winter soft wheat seeds treated with microwave (MW) and low frequency (LF) EMF with different exposures. In a microwave setup, the duration of treatment was from 10 to 120 s, and in a low frequency setup at a magnetic induction of 9 mT, from 3 to 5 min [2].

However, the use of MW treatment has a number of disadvantages – it is energy-consuming, causes thermal effects (heating of materials), which is undesirable for seed grain, is difficult in design, and also requires protection of maintenance personnel from harmful MX radiation.

More natural for biological objects is the EMF of low and extremely low frequencies (LF and ELF). Generating these frequencies is much easier than MW frequencies, grain treatment does not cause thermal effects. However, there are practically no results from studies of wheat grain treatment in the ELF range.

Thus, the study of the modes of treatment grain with ELF EMF, which make it possible to improve the quality indicators of wheat grain, in particular its germination, is an urgent task.

2. The object of research and its technological audit

2.1. The object of research. *The object of research* is the treatment of wheat grain with ELF EMF, the subject of research are the quality indicators of seed grain of wheat varieties Shestopalivka 2021 and 2020 crop grown in the Odesa region (Ukraine).

One of the problematic issues in the treatment of grain with ELF EMF is the justification of the duration of treatment of grain and the determination of the EMF frequency, which will improve the quality of wheat seed grain – germination and uniformity of germination.

2.2. Primary data collection procedure. The treatment of wheat grain with ELF EMF was carried out on an experimental setup, the general view of which is shown in Fig. 1.

The installation consists of a grain container (3), which is inserted into a polymer pipe (2) with a solenoid coil (1) wound on it, a GZ-112/1 electromagnetic oscillation generator manufactured in the USSR (8) and a low-frequency power amplifier (7) (LF). The output signal of the generator was set in the form of a sinusoid and controlled by an S1-78 oscilloscope manufactured in the USSR (4). The devices are interconnected in the required sequence by cables (5).

The required value of the magnetic induction of 10 mT was provided by stabilizing the voltage at a level of 3.6 V. To do this, before the start of each experiment in treatment grain, the required voltage value was set with the power regulator of the LF amplifier, which was controlled by a universal (combined) digital voltmeter B7-38 (6).

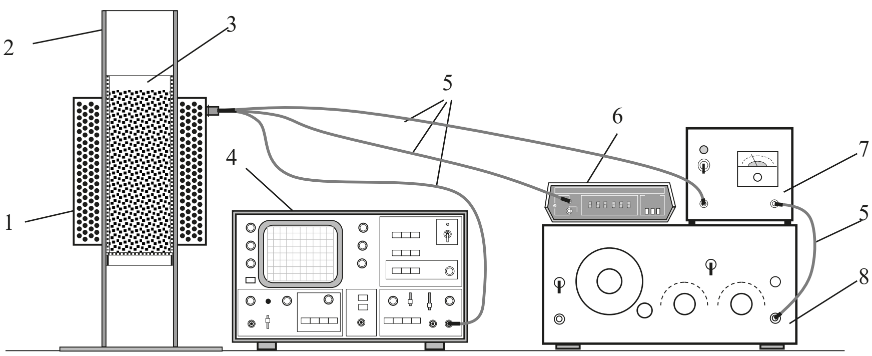

Fig. 1. Scheme of the experimental setup for treatment grain with ELF EMF:
1 – solenoid coil; 2 – polymer pipe; 3 – tank for grain; 4 – oscilloscope S1-78; 5 – connecting cables; 6 – universal (combined) digital voltmeter B7-38; 7 – low frequency amplifier; 8 – generator of electromagnetic oscillations GZ-112/1; (cables for connecting devices to a 220 V network are conditionally not shown)

The duration of grain treatment was 6 and 60 min.

Determination of quality indicators of treated and untreated (control) wheat seed grain was carried out immediately after EMF treatment, as well as after temporary storage for 19 days (excluding 8 days for seed germination).

On the basis of the data obtained, graphical dependencies were built and the main statistical characteristics of the treated wheat seeds were determined.

3. The aim and objectives of the study

The aim of the study is to substantiate the modes of pre-sowing treatment of wheat grain with ELF EMF, which will improve the quality of wheat seed grain due to the low energy intensity of its treatment.

To achieve the aim, the following objectives were set:

1. Investigate the effect of the duration of treatment of wheat seed grains with ELF EMF on germination.
2. Investigate the effect of the duration of treatment of wheat grain with ELF EMF on the length and characteristics of germinated seed shoots.
3. Investigate the effect of the frequency of ELF EMF on the germination of wheat grain.

4. Research of existing solutions to the problem

In studies [2], it was found that the effect of biostimulation from exposure to ELF EMF decreases over time, however, with MW stimulation, the effect persists for quite a long time, at least 5 months. This fact confirms the hypothesis of various mechanisms occurring in the grain and causing the effect of biostimulation during LF and MW actions. It was also found that under the combined effect (MW+LF 30 Hz) there was a significant increase in the germination energy and laboratory germination compared to the control. The authors suggested that the appearance of a biostimulation effect under the action of EMF is a consequence of the activation of the processes of nutrient supply to the embryo. At the same time, metabolic processes in hydrated and germinating seeds are intensified, caused by the activation of MWs by the field of ions involved in these processes.

Another group of scientists conducted a study of the MW effect on the energy of growth and the ability to germinate wheat grain of the Natalka variety [3]. A grain of wheat was moved by a conveyor through a magnetic field created by permanent magnets. The magnetic induction was regulated by changing the distance between the magnets within 0–0.5 T. The speed of seed movement through the MW was 0.4 m/s, and the temperature was 20 °C.

It has been established that the change in the energy of germination and germination of wheat grain during magnetic treatment depends on the square of magnetic induction and the speed of movement of seeds in the MW. The optimal treatment mode takes place at a magnetic induction of 0.065 T.

The scientists also cite the results of the study, indicating that under the influence of MW on the grain, the rate of chemical reactions increases, which leads to stimulation of the seeds. This increases the solubility of salts and acids contained in the plant cell. MW promotes the acceleration of diffusion of molecules through the cell membrane, in particular oxygen. This increases the water absorption of the grain. Under the influence of MW, the transport of ions through the cell membrane increases, increasing the concentration of mineral substances in the cell.

The possibility of improving the yield of the crop using EMF in [4] is assumed, given the presence of thresholds for the energy resources of each plant, created by nature at the genotype level.

The paper [5] considers the use of pulsed electromagnetic radiation for the disinfection of a grain mixture. Based on the above data, experts conclude that exposure to EMF on grain for a limited time intervals is possible to destroy insect pests, because for heating the grain to an unacceptable temperature (ΔT=35 °C) from 20 to 55 °C will require significantly more time (about 900 s) than the time needed to destroy pests (enough 2 s).

Also from the theoretical work [6] it follows that the use of the MW method for disinfection and drying of seeds is more economical than the thermal method. It allows you to reduce the cost not only for energy carriers, but also to reduce the production areas allocated for fuel storage. When treatment EMF seeds, the equipment do not heat up, which allows, with the complex automation of the entire technological process, to carry out treatment in the optimal temperature regime without overheating of individual sections?

Despite the sufficient weight of recent studies of the effect of EMF on plants, they have not found practical implementation in agriculture, including Ukraine [7]. The author of the work believes that the acceleration of the solution of the problem of practical implementation can be carried out through research in the field of the biophysical and physiological mechanism of the influence of the energy exchange process in plant objects, taking into account the energy resource inherent in them by nature. Also, the development and creation of quantitative methods for measuring the germination energy for objective information about the required value of the energy resource, which will allow targeted regulation of the germination energy, taking into account their properties and individual characteristics.

A review of published studies on the use of EMF in agriculture over the past 40 years, carried out by a group of international scientists from China, Iran, India, Morocco and Brazil [8], indicates an increase in the number of publications in this area over the past 10 years. These works are connected with increase in productivity.

Dependence on EMF treatment regimes and the nature of seeds, established in experiments on studying the effect of low power MW radiation on the germination and growth rate of various seeds, including wheat, in [9].

In [10], experts present the results of studying the effect of treatment with LF MW (16 and 50 Hz) on the germination of seeds of different crops, including wheat. They concluded that variable LF MW (16 Hz) could be used as a post-crop treatment method to improve seed vigor of various plant species, as a method recommended for seeds germinating in adverse environmental conditions or poor quality seeds.

Somewhat later, other specialists came to the conclusion that, as a result of presowing treatment, EMF stimulation of seeds can have a positive, but mostly temporary and non-permanent effect on the percentage of germination, growth rate, and germination rate [11].

The opposite results of germination under the same conditions of treatment with ELF EMF seeds of *Brassicanapus L* (canola) and *Zeamays L* (corn) were obtained in studies [12].

The studies [13] studied the effect of pre-sowing seed treatment of extremely high frequency (EHF) EMF of low intensity (64 mW/cm^2, 51.8 GHz) on seed germination and productivity of wheat seedlings. The effect of different durations of exposure (3, 5 and 10 minutes) on the germination of treated wheat seeds was studied. They found that a 5-minute EMF treatment could significantly improve vigor (by 7.0 %) and germination (by 8.0 %) compared to the control group. At the same time, shoot height (by 10 %) and wet weight (by 12 %) improved significantly in the ladder stage. However, a decrease in germination rate was observed in the longer (10 min.) treatment groups.

The prospects for using treatment with the help of the RIES method (resonant impulse electromagnetic stimulation), developed at the Faculty of Agriculture of the University of Novi Sad, are discussed in [14].

EMF treatment is also included in the list of recent advances in physical post-crop treatment to increase the shelf life of cereals, reviewed in [15].

Also, attention has recently increased to the study of the influence of the ELF EMF range on biological objects in order to use them for storing agricultural products [16].

It follows from the reviewed literature that the properties of EMF have a significant potential for application in agriculture, which is practically not used in Ukraine today.

Setting the grain germination parameters is a reliable and affordable method for determining the response of the EMF effect on wheat and determining the physiological state of the grain. This may be the basis for the transition from theory to practical use of EMF, based on a careful (careful) study of the germination of the treated grain in relation to treatment modes.

Given the low energy consumption compared to high-frequency treatment, the method of exposure to ELF EMF becomes interesting. But there are no studies on the germination of wheat after treatment with ELF EMF.

Thus, the foregoing provides a basis for conducting the necessary studies to study the effect of ELF EMF on the quality indicators of wheat seed grain during its presowing treatment, which will increase its germination and yield.

5. Methods of research

The following methods were used in the conducted studies. Seed properties of grain were characterized by the indicator of laboratory germination determined by DSTU 4138-2002 «Seeds of agricultural crops. Methods for determining quality». The essence of the method was to place 100 grains of the studied samples of wheat grains on moistened filter paper, germinate them in a thermostat at the optimum temperature (20±2 °C) for 8 days and count the number of normally developed seeds. Permissible deviations of wheat grain germination in individual samples from the average value were within the limits provided for by DSTU 4138-2002.

To establish the effect of EMF treatment of grain on its seed properties, in addition to germination, the length and main statistical characteristics of the variation rows of germinated sprouts were additionally determined. In particular, their arithmetic mean, mode, median, minimum and maximum length, standard deviation, coefficients of asymmetry, kurtosis, and variation were determined [17]. The length of the sprouts was measured with a measuring ruler with a scale division of 1 mm.

6. Research results

6.1. Influence of the duration of treatment of seed grain of wheat with ELF EMF on its germination. At the first stage of the research, the influence of the duration of treatment of wheat grain of the Shestopalivka variety of 2020 crop on the germination and intensity of grain germination was studied. The treatment of grain samples with EMF with a frequency of 30 Hz and a magnetic induction of 10 mT was carried out for 6 and 60 min. The control sample taken for comparison was not treated with EMF. The grain treated with EMF on December 05, 2020 to determine germination was placed for germination immediately after treatment, and the grain treated on November 26, 2020 after 19 days of intermediate storage. According to the method for determining the germination of grain (DSTU 4138-2002), on the 8th day, the number of germinated grains was counted, and the length of germinated grain sprouts was also measured. Comparative characteristics of the change in the germination of the grain of the treated EMF and control depending on the duration of treatment and the presence of intermediate storage is clearly visible in Fig. 2.

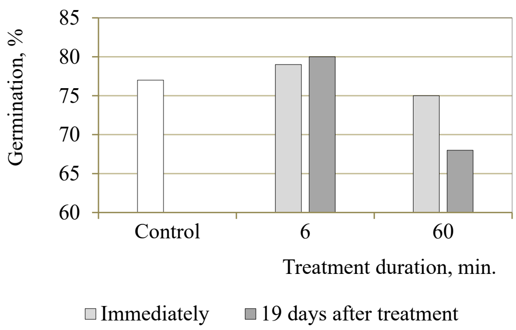

Fig. 2. Dependence of the germination of wheat grain on the duration of EMF treatment and intermediate storage

It can be seen that the germination of the control (not processed) grain samples was 77 %. After grain treatment with EMF for 6 min. its immediately determined germination increased in relation to the control to 79 %, and after 19 days of storage it increased to 80 %. However, according to the method for determining the germination of the grain, these changes in germination relative to the control are within tolerance (±8 %) and are considered insignificant.

When treatment grain for 60 min. the immediately determined germination with respect to the control decreased to 75 %, and after intermediate storage for 19 days, it still decreased to 68 %, which is already considered statistically significant.

Thus, treatment grain with EMF with a frequency of 30 Hz, a magnetic induction of 10 mT and duration of 6 min. can slightly increase seed germination within tolerance limits. Seed treatment for 60 min. tends to reduce the germination of wheat grain to 9 %.

From an energy point of view, seed treatment for 60 min., in addition to reducing germination, will also lead to a 10-fold overexpenditure of electricity for generating EMF oscillations.

6.2. Influence of treatment with ELF EMF on the characteristics of germinated shoots of wheat seeds. According to the research methodology, in addition to the germination of the grain, the lengths of all germinated sprouts and their statistical characteristics were also determined. For this, the obtained shoot length values were divided into groups (classes) with an interval of 20 mm, their number in each class was counted, and the share they occupy in relation to the total number of germinated grains was determined. According to the data obtained, histograms of the distribution of grain shoots by their length classes were constructed for the control and processed 6 and 60 min. (Fig. 3).

From Fig. 3, *a*, it can be seen that when treatment grain with EMF for 6 min. more uniform grain germination. With the beginning of grain germination, the germination rate (length of sprouts) increased and the largest proportion of sprouts that reached a length of 81–100 mm was 24 %. Subsequently, a rapid decline in the proportion of longer grains was observed. The largest sprout reached a length of 150 mm. The main part of the grain had sprouts in the range of 61–120 mm, which was 62 % and 1.29 times more than the control.

The grain treated for 60 min. germinated worse and the proportion of germinated grains of greater length (in the range of 21–60 mm) gradually decreased. And only the main proportion of sprouts with a length of 61–120 mm increased significantly, reaching 19–20 %, which exceeded the control by 1.23 times. The sprout in the range of 121–140 mm was only 2 %, and the greatest length (137 mm) was only 2 pieces.

As can be seen from the graph of the line of distribution of the length of sprouts of the control sample (Fig. 3, *a*), the proportion of sprouts with a length in the range of 1–80 mm was almost the same – in the range of 8–11 %. The largest share (23 %) was sprouts with a length of 81–100 mm, and the smallest (1 %), with a length of up to 140 mm.

It should also be noted that before reaching the sprout length of 41–60 mm, the untreated grain gave a greater length than after EMF treatment. According to the literature data, this can be associated with the stress state of the grain during its treatment with EMF.

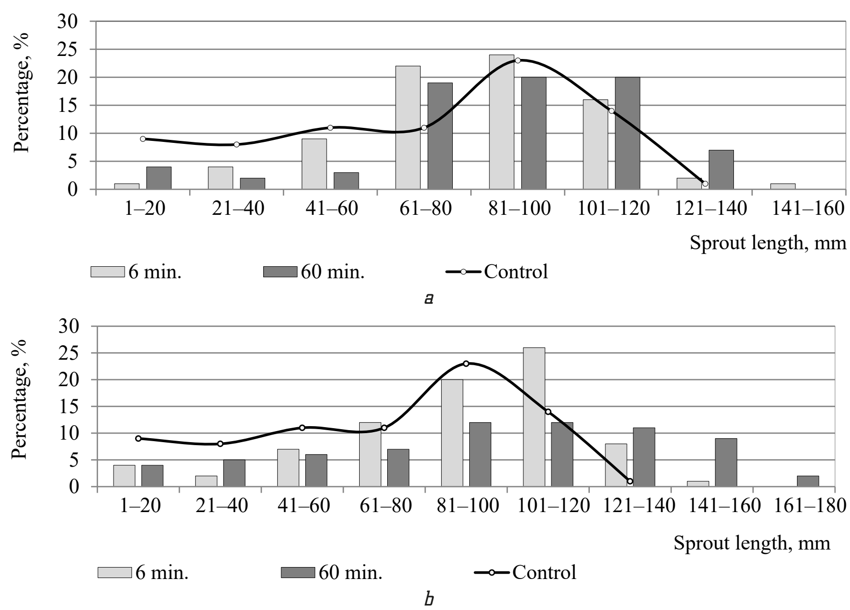

Fig. 3. Distribution of the length of wheat seedlings at different durations of EMF treatment: *a* – determination of germination immediately after treatment; *b* – determination of germination 19 days after treatment

However, subsequently the grain is activated, and this, compared with the control, increases the rate of grain germination, which almost doubles its share with a sprout length of 61–80 mm. In the future, untreated grain has a smaller proportion of sprouts of greater length.

Thus, the treatment of grain with EMF for 60 min. gives slightly worse germination results compared to a 6 min. treatment. In addition, a longer EMF treatment will lead to a 10-fold overexpenditure of energy for treatment.

A similar treatment of grain with EMF was carried out on November 26, 2020, and the determination of germination and the length of germinated sprouts was carried out on December 23, 2020, that is, 19 days after treatment. Determination of the germination of grain treated with EMF for 6 and 60 min. showed that it was 80 % and 68 %, respectively. That is, long-term treatment of grain with EMF (60 min.) after its storage for 19 days led to a decrease in grain germination compared to short-term treatment (6 min.) by 1.18 times. In addition, from those shown in Fig. 3, *b* of the histograms, it can be seen that the treatment in 6 min. gave a significantly larger (1.7–2.2 times) proportion of longer sprouts in the range of 61–120 mm, compared with EMF treatment of grain for 60 min.

The conducted studies have shown that, both in terms of germination and the particle size of longer seedlings, EMF treatment of grain for 6 min can be considered more effective. It is shown that the effect of germination activation of EMF-treated grain increased after 19 days of its storage.

In addition to constructing and analyzing the histograms of the distribution of shoots along the length, a number of other statistical characteristics of the variation series by the length of the shoots were determined. Among them: characteristics of the position (mean values, medians and modes), scattering (minimum and maximum sizes, sample standard deviations) and distribution forms (asymmetry and kurtosis coefficients). The obtained values of these characteristics are given in Table 1.

Table 1

The main statistical characteristics of the length of the sprouts of the control and treated with EMF wheat grain samples for 6 and 60 min

Characteristics	Control	Determination of characteristics after treatment			
		immediately		after 19 days	
		6 min.	60 min.	6 min.	60 min.
Arithmetic mean $L_{a.m.}$, mm	70.9	83.1	88.9	92.9	97.2
Mode *Mo*, mm	10	85	95	120	30
Median *Me*, mm	80.0	85.0	94.0	97.5	101.5
Minimal length L_{min}, mm	10	20	10	10	15
Maximal length L_{max}, mm	125	150	137	142	175
Standard deviation *S*, mm	32.5	24.8	28.2	30.4	42.1
Asymmetry coefficient *A*	–0.40	–0.12	–0.84	–0.94	–0.33
Kurtosis coefficient *E*	–0.96	0.11	0.79	0.62	–0.88
Variation coefficient *V*, %	45.84	29.88	31.73	32.74	43.30

Characteristics of shoots determined immediately after EMF treatment of wheat grain samples for 6 and 60 min. show that they are longer than the control 12.2–18.0 mm from their arithmetic mean values. It can also be seen that, compared with the control, in the samples of the length of the shoots from the treated grain, the minimum and maximum sizes are large, the most common are significantly longer shoots (mode), they have higher medians, a smaller spread of values relative to the average values (smaller standard deviations). Sprouted sprouts have an uneven length – their coefficient of variation exceeds 20 %. However, the sprouts of EMF-treated seeds are still 1.44–1.53 times more uniform in terms of coefficients of variation than the control (untreated seeds). Sprouts also give a form of distribution curves (histograms) closer to the normal distribution, as evidenced by the smaller values of the coefficients *A* and *E*.

This confirms the positive role of short-term (6 min.) EMF treatment of grain in its germination and characteristics of germinated sprouts.

The statistical characteristics of grain sprouts, which remained after treatment for 19 days, have changes similar to the considered regularities. They are distinguished from the previous ones by slightly increased arithmetic mean values of the length of the sprouts, their medians, and the maximum length (when treatment 60 min.). But at the same time, the unevenness of the shoots along the length increased, especially those treated for 60 min. Coefficients of variation in shoot length compared to characteristics determined immediately after 6 and 60 min. treatment, increased respectively by 1.10–1.36 times, that is, the sprouts germinated more unevenly.

Therefore, a comparison of the statistical characteristics of sprouts of grain samples that were stored for 19 days also confirms the advantages of grain treatment with EMF for 6 min.

As for the shape of the shoot length distribution curve, it can be noted that for the control and processed for 6 and 60 min. grain samples, the coefficients of asymmetry are negative – that is, most of the sprouts have a length less than average. It can also be seen that the kurtosis coefficients for the distribution of the length of the seedlings of the control and the sample treated for 60 min and persisted for 19 days, are negative. This indicates that the maximum of the experimental sprout length distribution is below normal. For other samples, it is higher than normal.

6.3. Influence of the frequency of ELF EMF on the germination of wheat grain. A subsequent series of studies was carried out to establish the influence of EMF frequency features on the germination of wheat grain. The wheat grain of the Shestopalivka variety of 2019 and 2020 crop was subjected to treatment. The EMF frequencies were varied within 15–17 Hz with a step of 0.5 Hz. The EMF intensity was 10 mT, and the treatment lasted 6 min. The germination of the treated and control (not treated) grain samples were determined by the method described above. The results of the germination are given in Table 2. It also shows the values of deviations of grain germination from average values (control) according to DSTU 4138-2002.

As evidenced by the data obtained, the germination of EMF-treated wheat grain in 2019 practically did not change – it fluctuated by ±3, which is less than the permissible error (5 %). The germination of the processed wheat grain of 2020 crop varied from –13 % to +1 %. These results indicate that the treatment of grain in the studied frequency range led to a significant decrease in grain germination. The only exception was the frequency of 16.5 Hz, at which the germination remained practically unchanged. Thus, the effect of treatment wheat grain of the Shestopalivka variety harvested in 2019–2020 in a narrow frequency range of EMF (15–17 Hz) is different depending on the crop year, but in 2020 it mainly reduced grain germination.

Table 2

Germination of wheat grain treated with different EMF frequencies

Crop year	Control	EMF frequencies, Hz										Permissible deviations, %
		15.0	15.5	16.0	16.5	17.0	15.0	15.5	16.0	16.5	17.0	
	Germination, %						Deviations from control, %					
2019	92	92	95	89	93	95	0	3	–3	1	3	5
2020	88	82	84	79	89	75	–6	–4	–9	1	–13	6

7. SWOT analysis of research results

Strengths. The strengths of this research are that presowing EMF treatment of wheat seed grain is short-term, low-energy, technologically simple, does not require the use of complex seed activation methods (cold treatment, radioisotopes, electron beams, etc.) and the use of various chemicals presowing activation of seeds. It is also important that the proposed seed treatment is also environmentally friendly both for seeds and for servicing electrical activators, since the ELF EMF range, unlike microwave, is natural for wheat seeds as a living organism and cannot cause thermal or other damage to seeds.

Weaknesses. The weaknesses of the conducted research are related to the fact that in order to implement the obtained scientific results in industrial conditions, it is necessary to create special electrical equipment for treatment and activating seed grain with EMF VNP before sowing.

Opportunities. Additional opportunities when using these results in industrial conditions are related to the fact that the treatment of seed grain of wheat with ELF EMF also allows to partially reduce the microbiological contamination and infection of the grain with pests [6], which makes it possible to reduce or avoid the use of chemical methods of seed treatment.

Threats. Some threats of the regimes of EMF grain treatment proposed in this paper may be related to the fact that they are obtained in laboratory conditions. Their further practical verification in the field conditions of farms engaged in the cultivation of wheat grain and a more substantiated economic assessment of the proposed method of seed treatment are necessary. The results obtained are nevertheless confirmed in the literature sources cited above.

8. Conclusions

1. On the basis of the conducted studies, it was found that, compared with untreated grain, the treatment of grain with an EMF with a frequency of 30 Hz, a magnetic induction of 10 mT and a duration of 6 minutes increases the germination of seeds, determined immediately after treatment, by 2 %, and determined after 19 days by 3 %, which lies within the tolerance limits.

Seed treatment for 60 min. has the opposite trend – leads to a decrease in the germination of wheat seeds, determined immediately after treatment by 5 %, and after 19 days – already by 9 %. The last decrease exceeds the allowable normalized deviation.

From an energy point of view, seed treatment for 60 min., in addition to reducing germination, will lead to an overexpenditure of electricity for EMF treatment by 10 times.

2. Analysis of the statistical characteristics of shoot length determined immediately after EMF treatment of wheat grain samples for 6 and 60 min. showed that sprouts are longer than 12.2–18.0 mm compared to untreated grain (control). They also have a smaller spread in length relative to their arithmetic mean values, and in terms of coefficients of variation they are 1.44–1.53 times more uniform. It has been established that the indicated characteristics of the shoots of grain processed for 6 minutes are preferred over 60 min.

The statistical characteristics of grain sprouts, which were preserved after treatment for 19 days, have similar patterns of change. They have slightly increased arithmetic mean values of the length of the sprouts, median and maximum after treatment 60 min. length. However, the unevenness of the shoots along the length increased by 1.10–1.36 times, especially those treated for 60 min. Thus, a comparison of the statistical characteristics of the length of grain sprouts, which lasted 19 days, also confirms the advantages of grain treatment with EMF for 6 min.

3. It has been established that the treatment of wheat grain in 2019 with ELF EMF at a frequency of 15–17 Hz with a magnetic induction of 10 mT for 6 min. practically did not change the germination – it fluctuated within ±3 % of the control, which is less than the permissible error (5 %). The germination of the processed wheat grain of 2020 crop varied from −13 % to +1 %, which led to a significant decrease in the germination of grain, with the exception of a frequency of 16.5 Hz, at which it practically did not change. It is also shown that the effect of treatment wheat grain of the Shestopalivka variety 2019–2020 crop in a narrow range of EMF frequencies (15–17 Hz) was different – in 2020 it mainly led to a decrease in grain germination.

The results obtained encourage further research with a more detailed study of the effect of EMF grain treatment in a wider range of ELFs and areas of cultivated wheat.

Conflict of interests

The authors declare that there is no conflict of interest regarding this study, including financial, personal nature, authorship or other nature that could affect the research and its results presented in this article.

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