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The Processing of Seeds of Spring Wheat by Low Frequency Electromagnetic Field in An Industrial Environment

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***Abstract*: The article compares the results of the electromagnetic field of low-frequency radiation on the seeds of spring wheat in industrial equipment and in the laboratory. It is shown that in both technologies the stimulation of seeds by the electromagnetic field achieves a similar increase in the yield of plants. The effect of the electromagnetic field is determined by the mode of exposure, the frequency of low-frequency radiation, the duration of irradiation of seeds. With the help of optical and electron microscopy with microelement analysis, it was found that the electromagnetic field generated in industrial equipment changes the structure and distribution of elements in the outer shells of wheat grains, which increases the growth rate of the plant.**

***Index Terms*: electromagnetic field of low-frequency radiation, irradiation mode, grain structure, electron and optimistic microscopy, microelement analysis.**

I. INTRODUCTION

Nowadays there are numerous studies aimed at developing technologies that use various sources of stimulation of plant growth and development with the help of energy factors.There are works that have a thirty-year history, in which the impact of weak physical factors led to the stimulation of crop yields and improve the quality of the crop [1,2]. Other papers [3,4] provide experimental data on the effect of high - frequency EMF and also UV-radiation on the growth, development, productivity and activity of endogenous wheat growth regulators. However, despite numerous studies, the problem of the stimulating effect of physical factors has not yet been solved completely even in the laboratory. To date, there is no consensus among the scientific community and specialists of the agro-industrial complex on the effectiveness of processing of biological systems by different types of electromagnetic radiation. In some cases, such treatment leads to a positive, in some cases, to a negative effect. There is a vividly expressed nonlinearity of effects. There is also the problem of specifically reduced reproducibility of the same effects in different laboratories. These facts make it difficult to solve the problem of introduction of physical stimulation of
seeds of agricultural crops in industrial technology.

The differences of the obtained effects is caused on the one hand, by the different responses of biological systems to the effects of radiations of different nature, due to the different mechanisms of physical phenomena, which are implemented in irradiated plant. On the other hand, this is due to many factors that determine the nature of changes in biochemical photochemical and oxidative processes occurring in the plant under the influence of a physical factor. A significant role in biomass accumulation is played by the quality of seed material and environmental conditions [5]. The dependence of the nature of the influence of physical action on its nature, intensity, radiation dose [6]. It is an important technological task to assess the impact of wheat seed treatment by low-frequency electromagnetic field on the yield in an industrial setting in the field. It is important, taking into account the conditions of manifestation of the magneto effect, to ensure the design of technological equipment, technological methods, modes and conditions of treatment of plant seeds to achieve high results. The purpose of the work is to study the features of the influence of the electromagnetic field of low - frequency radiation on the germination and growth of spring wheat irradiated in an industrial plant.

II. MATERIALS AND METHODS

Seeds of spring wheat of the “Omsk 18” variety (“Ulanskaya MTS LLP” East Kazakhstan) were processed by the electromagnetic field of low-frequency radiation (EMF) with the help of an industrial stationary device, which is based on a system of low-frequency emitters with a frequency varying within 3-16 Hz, with an induction of 6 mTl.

The influence of the processing conditions of electromagnetic fields on the germination of seeds was determined, recording the biometric parameters of seedlings of the control and irradiated seeds of wheat, grown in laboratory conditions in Petri dishes by the method of State Standard 12038-84. Seed germination was carried out in a thermostat in the dark. The repetition of samples to 4-fold. Each sample contained 100 seeds. Germination energy was determined on the 3rd day, germination – on the 7th day, biometric parameters on the 10th day.Morphology of the inner part of the grain was studied using a polarization optical microscope with computer connection (manufactured by CarlZeiss).

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Longitudinal sections with a thickness of ~1, 3, 5 mm were analyzed.Electron-microscopic analysis was held using a scanning electron microscope (manufactured by JEOL, Japan). Transverse sections of 3-5 mm were examined. A scanning electron microscope was combined with an energy-dispersive x-ray spectrometer JSM 6510LA to conduct microelement analysis. Experimental data are processed with the help of dispersion and correlation analysis according to “AGROS -2.02 " programs.

III. RESULTS AND DISCUSSION

The main problem of processing wheat seeds by electromagnetic field of low-frequency radiation in an industrial installation, when a large mass of grain is subjected to magnetization, is the effectiveness of EMF.

The latter depends on the degree of uniformity of irradiation, therefore, on the construction of the industrial plant equipped with emitters. To answer this question, the morphological parameters of four batches of seeds magnetized under the same conditions were compared. For the parameter controlling the homogeneity of the irradiation was taken biometric parameters of seedlings grown from seed of wheat on the 10th day. An example of changes in the length of the plant grown from seeds treated with radiation at a frequency of 16 Hz, 6 mTl for 10 minutes within one batch of 100 seeds is shown in the curves fig.1.

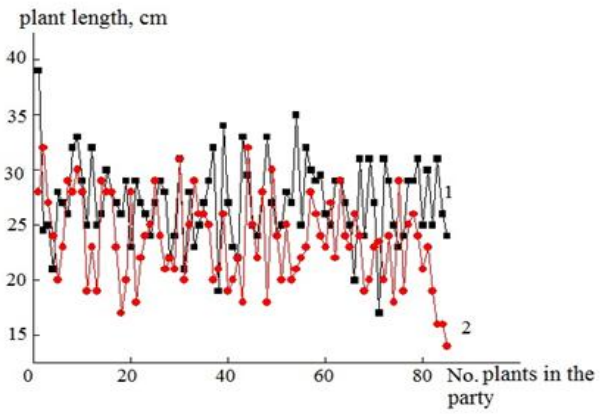

Fig.1. Curves characterizing the distribution of wheat plant lengths within the batch, depending on the number of plants in the batch. Curve (1) for plants grown from seeds irradiated at 16 Hz, 6 mTl for 10 min, curve (2) for control non-magnetized seeds. (To the article by Alchimbaeva A. S. with co-author).

As can be seen, the spread due to the heterogeneity of the parameters of plants grown from magnetized seeds is close to the spread of similar parameters in the initial untreated seeds. The latter are control samples. The limits within which the morphological parameters of wheat change indicate that regardless of the mass of the heap of irradiated grain, it is possible to achieve an acceptable degree of homogeneity of seed magnetization and, consequently, high processing efficiency.The second important aspect of the problem of effective work of EMF in industrial equipment are its operating conditions. To determine the factors determining the effectiveness of low-frequency EMF radiation effect on seed germination and growth, the dependence of plant parameters grown from the magnetized seeds of spring wheat on the modes and time of exposure to them was established. The grain was processed by a magnetic field with magnetic induction (B) = 6 mTl., according to three programs, at frequencies: 3, 10 and 16 Hz, in a moving grain flow and in a still grain mass. At the same time, the times of the magnetic field exposure were varied.

The parameters characterizing the influence of LF EMF on the germination rate of seed samples treated in different modes for different times are presented (table.1).

Table 1. Parameters of plants grown in Petri dishes from seeds treated with a magnetic field for 10 days.

The number of samples of grain, No.	processing conditions		Processing time, min.	Plant weight, mg	The length of the sprout in the plant, cm	The mass of the sprout to the plant, mg	Root length in the plant, cm	The weight of the root in the plant, mg
	mode	frequency, Hz						

*1	-	-	0	59.8-97.3	14.0-16.5	40.3-65.0	6.0-9.5	19.5-3
2	flo	3	2.5	50.2-80.5	9.0-17.5	28.2-41.6	3.5-6.5	2.0
3	w	10	2.5	53.3-70.5	10.5-11.0	30.0-42.8	6.0-8.0	19.0
4	flo	16	2.5	55.3-80.5	12.5-13.0	29.0-43.5	7.0-9.0	20.7-2
5	w	10	3	56.5-106.	13.5-17.5	43.6-64.9	6.5-9.0	7.5
6	flo	10	6	6	15.0-16.0	32.0-50.9	8.0-9.5	21.0-3
7	w	10	9	54.0-97.5	13.0-19.0	34.0-65.5	10.0-10.5	6.0
8	stat	16	3	63.0-107.	14.0-16.0	53.0-60.0	9.0-12.0	13.0-3
9	ics	16	6	5	16.0-22.0	58.1-65.0	6.0-8.5	2.0
10	stat	16	9	85.0-97.3	15.0- 15.5	72.6-75.9	5.0-10.0	25-40
11	ics	16	20	72.3-90.6	13.0-15.5	52.8-65.5	6.0-9.0	30.0-4
	stat			92.3-100.				1.0
	ics			8				32.0-3
	stat			75.2-104.				7.0
	ics			6				12.4-2
	stat							5.1
	ics							19.1-2
	stat							3.3
	ics							21.6-3
	stat							8.2
	ics							

*1 – control experiment. These data are obtained for 100 seeds

As can be seen from the table, the biometric parameters of plants grown from seeds on the 10th day depend on the irradiation conditions. When irradiated in static mode, the impact of EMF on seeds is much greater than in the stream. At the same time, the mass and length of wheat germ tend to increase with increasing processing time. The greatest impact of treatment in terms of exposure frequency of 16 Hz.
Analysis of wheat seeds treated with EMF at 16 Hz, 6 mTl showed that compared with the control samples, the vegetative mass of irradiated seeds increases by 15÷ 55 %, the mass of 1000 grains by 11 ÷ 43 %, the height of plants in the tillering phase - from 10 to 25%, the mass of the dry fraction of plants increased to 50%. To predict the efficiency of the industrial plant, it is necessary to find out the mechanisms by which EMF leads to the effect of stimulation of plant seed growth. To this end, the paper studied the features of changes in the parameters of grains, occurring as a result of exposure to EMF, by optical, electron microscopy, coupled with x-ray elemental analysis.From the comparison of microscopy data of samples treated in different modes, it follows a conclusion similar to that obtained from the comparison of biometric parameters of sprouted seeds: when irradiated in static mode, the effect of EMF is much greater than in the flow. The greatest impact gives treatment in terms of exposure frequency of 16 Hz.The analysis of microphotographs of the grain surface with the help of an optical microscope showed a significant effect of EMF on its structure - there is a decrease in the roughness of the peel. Compare paintings of the longitudinal sections of the grains irradiated, and the source of the seeds of wheat, reflects the structure of the endosperm and embryo, demonstrate the movement of minerals that have crystal-like structure (we can assume that the crystallites of water) from the endosperm to the embryo (fig. 2).

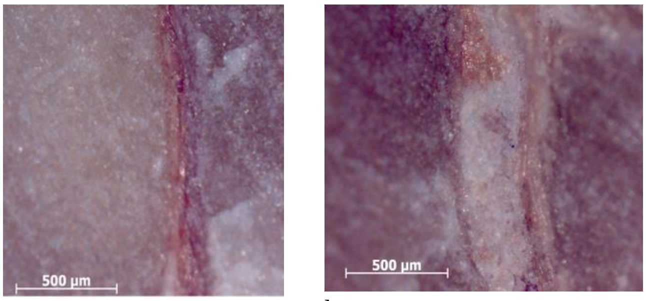

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Fig. 2. Microphotographs of longitudinal sections of initial (a) and magnetized (b) seed samples demonstrating endosperm and embryo obtained by optical microscope (To the article by Alchimbaeva A. S. with co-author).

Optical microscopy also demonstrates changes in the cellular structure of the endosperm (fig. 3 a, b). The size and orientation of the cells change.

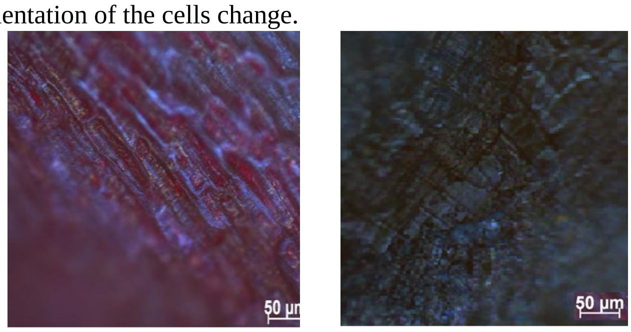

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Fig. 3. Microphotographs of the cell structure of the endosperm of the initial (1) and magnetized (2) seed samples obtained by an optical microscope (To the article by Alchimbaeva A. S. with co-author).

The change in the cell structure and composition of individual layers of grain in the magnetized wheat seed is confirmed by electron microscopy data (fig.4 a, b). Electron microscopic analysis of control and magnetized samples of wheat was carried out in the laboratory "Electron microscopy" in the Kazakh-Japanese innovation center of the Kazakh national agrarian university on a scanning electron microscope complete with energy dispersive x-ray spectrometer brand JSM 6510 LA of Japan JEOL company production.

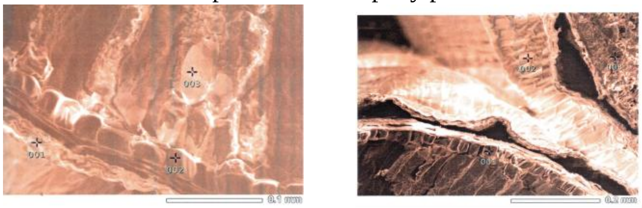

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Fig. 4. Electronic microphotography of the cross section of the control (untreated EMF) grain (a) and grain magnetized at 16 Hz (b). The longitudinal (001), transverse (002) cells of the outer layer, the aleurone layer of endosperm (003) grains are presented. (To the article by Alchimbaeva A. S. with co-author.)

The average size of samples was 3-5 mm. For effective analysis has been prepared transverse sections of seeds. Electron micrographs of magnetized and control grains are presented in fig. 4a and 4b respectively. In both images, micrographs of grain sections demonstrate the outer layer consisting of longitudinal (001) and transverse cells (002), as well as the aleurone layer (003) of the endosperm. The comparison of fig. 4a and 4b shows that EMF processing in the grain section changes the orientation of structural elements, in the aleurone layer there is the appearance of loose areas.Simultaneously with electron microscopic analysis was conducted microelement analysis. A sample of the spectral pattern of microelement analysis showed peaks, the intensity of which corresponds to the content of ion atoms. The results of microelement analysis of samples of non-magnetized and processed EMF are given in table 2 and 3 respectively. The tables show the calculated concentrations of elements and ions C,O, P, K+, Mg+2,Al3+ .

In the control samples, elements evenly distributed over the shells were found: C, O, and in a small amount of AL3+, K+and Mg+2 ions. The Central parts of the sample (the aleurone layer) contain C, O, P, and ions of K+, Mg+2, because of the grain mass distribution, their local concentration is lower than the measurement accuracy of the device (table 2).

Table 2. Microelement composition of the shell and the endosperm of control (untreated EMF) grain

Layer No.	Element	Instrument factor, kev	Massa,%	Experimental error,%	Content of atoms,%	Ion content, %
001	C	0.277	74.37	0.15	80.46	81.5448
	O	0.525	22.71	1.06	18.45	14.3127
	Al	1.486	0.79	0.27	0.38	0.9474
	K	3.312	2.14	0.56	0.71	3.1952
	Mg	0.0	0.0	-	0.0	0.00
			Total 100.00		Total 100.00	
002	C	0.277	78.81	0.17	83.38	86.8939
	O	0.525	20.52	1.25	16.30	12.30954
	Al	1.486	0.68	0.31	0.32	0.7966
	K	0.00	0.00	-	0.00	0.00
			Total 100.00		Total 100.00	
003	C	0.277	64.41	0.14	70.68	70.9694
	O	0.525	35.59	0.76	29.32	29.0306
	Mg	0.00	0.00	-	0.00	0.00
	P	0.00	0.00	-	0.00	0.00
	K	0.00	0.00	-	0.00	0.00
			Total 100.00		Total 100.00	

The outer shells are also dominated by C and O, but the former is larger and the latter is smaller than the Central region (003).EMF processing leads to noticeable changes in the content and distribution of different atoms and ions in different layers of the grain (table. 3). For example, in the outer shells of magnetized grains (table.2) there are elements C, O, P and ions K+ , Mg2+. Carbon and oxygen are redistributed between the inner and outer layers of the endosperm. From the aleurone (003) and outer (001) layers oxygen moves to the outer shell 002, and carbon – vice versa. The carbon-enriched region is 001 and 003, while 002 region depletes (table.2 and 3).

Table 3. Microelement composition of shells and endosperm of magnetized wheat grain

Layer No.	Element	Instrument factor, kev	Mass,%	Experimental error,%	Content of atoms,%	Ion content, %
001	C	0.277	79.11	0.20	86.54	71.6859
	O	0.525	11.55	0.92	9.48	9.1919
	Mg	1.253	0.44	0.20	0.24	0.7103
	P	2.013	8.45	0.25	3.59	17.4957
	K	3.312	0.44	0.45	0.15	0.9162
			Total 100.00		Total 100.00	
002	C	0.277	62.27	0.14	69.76	64.2851
	O	0.525	33.76	0.63	28.39	30.0436
	Al	1.486	3.17	0.20	1.58	4.3083
	K	3.312	0.8	0.41	0.27	1.3630
			Total 100.00		Total 100.00	
003	C	0.277	66.84	0.14	75.23	64.9730
	O	0.525	24.99	0.66	21.11	21.3023
	Mg	1.253.	2.47	0.18	1.38	3.3519
	P	2.013	3.51	0.22	1.53	6.3043
	K	3.312	2.19	0.38	0.76	4.0685
			Total 100.00		Total 100.00	

Thus, the results obtained by electron microscopic analysis in conjunction with the microelement analysis, allow us to conclude that the impact of the electromagnetic field of low-frequency radiation leads to the transfer of metal ions from the volume of the grain surface, i.e., to the outer layers and to the redistribution of oxygen and carbon content between these layers.It can be expected that the change in the structure of the elemental composition in different areas of the grain as a result of EMF treatment should contribute to a change in seed germination.

IV. CONCLUSION

Treatment of wheat seed mass by electromagnetic field of low-frequency radiation in industrial conditions is an effective technological operation and leads to a change in the structure and composition of the content of the grain. The identified changes contribute to the growth and development of the plant, increase germination and accelerate seed germination.

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