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Magnetic-pulse processing of seeds of berry crops

Andrey Yurievich Izmailov, Igor Gennadievich Smirnov, Dmitry Olegovich Khort*, Rostislav Alexandrovich Filippov, Alexey Igorevich Kutyrev

Federal Scientific Agricultural Engineering Center VIM, Moscow, Russian Federation

**Corresponding author: vim_sad@mail.ru*

Abstract

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The effect of a pulsed low-frequency magnetic field on the seed germination and the growth of seedlings of strawberry garden under different conditions of processing and functioning of the apparatus magnetic-pulse processing of plants (MPP) developed by us has been established experimentally. The research has shown that the value of the germination energy of seeds treated with a pulsed magnetic field varied from 29% to 47%, of germination from 34% to 48%. The highest value of their germination corresponds to an irradiation frequency of 16 Hz and an exposure time of 360 s with an induction value in the treatment zone of 5 mT. The maximum increment in the germination of irradiated seeds was 14% compared to the control sample. The positive effect of pulsed electromagnetic fields on linear dimensions of germs has been revealed. The increase in the biometric parameters of strawberry shoots affected their weight, compared to the control it increased by 33.3%.

Keywords: physical impact; presowing seed irradiation; electromagnetic field; horticulture

Various methods of physical influence on seeds of agricultural crops are known: ultraviolet, laser, X-ray radiation, ultrasonic waves, electromagnetic fields of various ranges (optical, infrared, radio frequency, low-frequency, microwave, etc.). Conditionally these methods can be divided into biological, chemical and physical.

Electromagnetic field, is one of the important environmental factors affecting the biological activity of plants, it affects the physiological, biochemical and biophysical characteristics of plants (Audus 1960; Ljubimov 1997; Galland et al. 2006; Avdeeva 2008). The analysis of literature sources shows that a safe and highly effective method of increasing the physiological potential of seeds is their irradiation with an electromagnetic field of low frequency (EMF LF). This method makes it possible to substantially increase the germination energy, the germination of seeds, to increase the growth of seedlings and seedlings and their survival in planting (Audus 1960). The beginning of the influence study of the magnetic field on biological organisms, including plants, refers to the second half of the XIX. century. The first documented publication by Reinke (1876), which presents the results of experiments related to the effect of magnetic field on plant development. Based on the data presented, no positive effect of the magnetic field on seed germination and plant growth was observed. In a later publication (Tolomei 1893) revealed the effect

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Table 1. Effect of magnetic field on fruit and berries

Name of plant	Part of plant	Exposure parameters: magn. induction (T), frequency (Hz)	Effect	Authors
Fragaria vesca	seedlings	0.096, 0.192 T 0.384 T	increase of productivity (+) increase of the No. of fruits (+)	Esitken, Turan (2004)
Fragaria ananassa	vegetative part	0.096 T, 50 Hz 0.192 T, 0.384 T, 50 Hz	yield (+); Ca, Mg (+) number of fruits (–); yield (–)	Esitken, Turan (2004)
Apricot, apple	seeds	60 mT	germination (+)	Chao, Walker (1967)
Fragaria, pear	seeds vegetative part	5 mT, 50–100 Hz 5 mT, 16 Hz	increase in germination energy (+) increase of productivity (+) increase fruits number (+)	Donetskikh (2017)

of faster germination of seeds in a magnetic field. This was the first study to demonstrate the effect of magnetotropism. The phenomenon of magnetochromatic was subsequently examined in more detail Audus (1960).

In the publication (Esitken, Turan 2004) when using MF with induction of 0.096 T with a frequency of 50 Hz, an increase in yield by 18% and the accumulation of calcium, magnesium ions in strawberry leaves was achieved. Impact on wild strawberry MF 0.096, 0.192 and 0.388 T in greenhouses increased the yield and the number of fruits per plant. With the increase of the magnetic induction value of more than 0.096 T, the yield and the number of fruits decreased. The increase in the power of the MF to 0.384 T increased the content of N, K, Ca, Mg, Cu, Fe, Mn, Na and Zn, but decreased the content of P and S.

Chao and Walker (1967) used a horseshoe-shaped magnet with magnetic induction of 0.06 T for proceeding stimulation of apple, peach and apricot seeds. Apple seeds, as a result of exposure to a magnetic field, germinated 5 days earlier than control seeds. Their germination lasted 18 days, which is shorter for a week than for unstimulated seeds. Germination of apricot seeds was observed earlier for 3 days.

Conducted researches of Federal State Budgetary Scientific Institution «All-Russian selection and technological Institute of horticulture and viticulture» (FSBSI VSTISP) (Donetskikh et al. 2017) showed that the efficiency improvement of pear in the conditions of tissue culture of viruses depended on the modes of magnetic-pulse processing. The application of MPP with a continuous linear increase in the frequency in the range of 50–100 Hz is provided on the rootstock of pear English the greatest yield of healthy plants from the virus complex – 75%. The established modes of processing vertically directed upward magnetic induction pulses with a frequency of 16 Hz for 2 s were used in industrial plantations. An increase in yields by 29% was revealed due to an increase in the number of strawberries garden (Carbonell et al. 1998).

An overview of the parameters and an assessment of the impact of the magnetic field on garden crops is presented in Table 1.

It should be noted that the effect of pulsed EMF LF on the sowing quality of seeds of garden plants has so far been little studied and is an urgent task of scientific and practical importance.

The development of magnetic impulse processing is constrained by the lack of specialized technical means and technological methods capable of realizing the processing of EMF LF plants in the field. To create the appropriate aggregates and instruments, it is necessary to conduct research to identify the most effective irradiation parameters and refine the parameters of the working organs, through the functions of the responsiveness of plants and organisms to the action of pulsed low-frequency magnetic radiation.

The purpose of the research is to experimentally establish the effect of a pulsed low-frequency magnetic field on the germination and growth of fruit seed in different modes of operation of the control unit.

MATERIAL AND METHODS

For the research, seeds of strawberry garden were used. In the experiment, an apparatus for magnetic-pulse processing of plants (MPP) was developed

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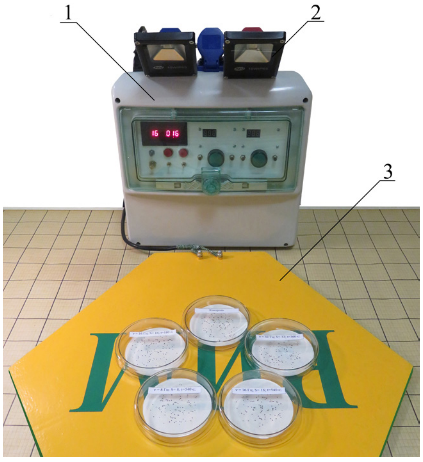

Fig. 1. Device for magnetic-pulse processing of plants

1 – control unit; 2 – light emitters; 3 – magnetic inductor

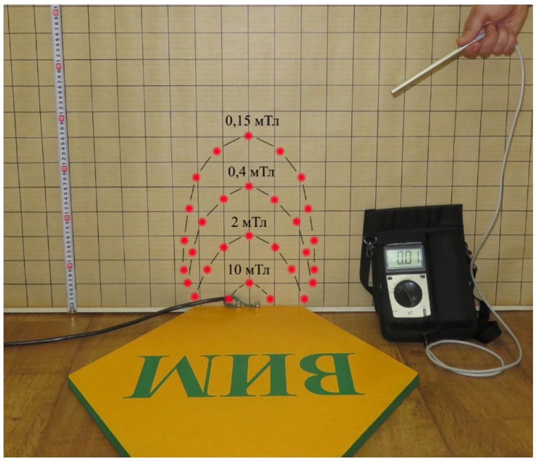

Fig. 2. Distribution of magnetic induction values of the plant MPP plants

as the emitter of a low-frequency pulsed magnetic field (Fig. 1).

The device is designed to stimulate vital and growth processes of garden plants, vegetable crops with a periodic sequence of pulses of magnetic induction in the low-frequency range with simultaneous additional synchronous irradiation with light pulses of certain wavelengths of the optical range. The work of the device is based on the transformation of the electric energy of the capacitor block into acting factors – the pulses of magnetic induction and light radiation (Khort et al. 2017).

The experiment involved 12 batches of 100 seeds per each and one lot of 100 seeds was taken as a control (not irradiated). Prior to irradiation, the seeds had the following characteristics:

Seed humidity was 7.09% and the mass of 1,000 seeds weighted 0.28 g.

The experiment was carried out at a constant temperature of 20°C.

The highest efficiency, according to various sources, has pulsed magnetic fields with a voltage close to the geomagnetic field of the earth. The induction of the pulsed magnetic field in the processing zone was 5 mT (Fig. 2).

The energy of germination was determined on day 14. Germination of seeds was determined on day 16. In determining the germinating capacity, in addition to decaying seeds, non-germinated seeds were taken into account. Irradiation parameters of seed samples: pulse repetition rate from 0 to 32 Hz; signal ratio from 0 to 32; exposure time 0 to 540 seconds. Laboratory studies were carried out in the laboratory of machine technology for cultivation and harvesting of fruit and berry crops FSAC VIM, using the analysis of literature data and information sources to justify the promising method, the parameters of electrophysical effects on garden plants and instrument-hardware base of magnetic pulse processing of plants in horticulture. To calculate inductance coils and to simulate the distribution of pulsed magnetic fields in space, we used a set of programs for engineering simulation of electromagnetic, thermal and mechanical problems by the finite element method ELCUT 6.0 pro and Coil32.

The following research equipment was used for conducting laboratory experiments: the millislameter portable universal (TPU-01; LLC «Zet», Russia), the digital oscilloscope AKIP 4122/1 (LLC «PROTEH», Russia), the Contador seed counter with the Contafill Container (LTD «Pfeuffer», Germany), the electric drying cabinet SESH-3M (JSC, Ukraine), the Memmert UFB 400 drybox (Memmert, Germany), the LP-113 thermostat Labor Muszeripari Muvek Esztergom, Hungary) moisture meter Kett FD 230 (KETT E.L., Japan), and analytical balance Sartorius LA230S (Sartorius Group, Germany).

As the Lodge was used filter paper. The device of magnetic pulse treatment of plants developed in FSAC VIM is used as the emitter of low-frequency pulsed magnetic field. The device is intended for stimulation of vital and growth processes of plants, periodic sequence of pulses of magnetic induction in the low-frequency range. The operation of the device is based on the conversion of electrical energy of the capacitor block into the acting factors – the pulses of magnetic induction and light radiation.

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Table 2. Parameters of seedlings on the 25th day

Batch No. (frequency Hz)	Av. sprouts height (mm) / control (%)	Av. root length (mm)/ control (%)	Av. weight of seedling (g)/ control (%)	No. of shoots (pcs)
1 (control)	10.8	4.6	0.0024	27
2–4 (2 Hz)	11.6 / 107.41	5.1 / 110.87	0.0027 / 112.50	105
5–7 (8 Hz)	12.2 / 112.96	5.4 / 117.39	0.0029 / 120.83	116
8–10 (16 Hz)	13.4 / 124.07	5.9 / 128.26	0.0032 / 133.33	127
11–13 (32 Hz)	12.4 / 114.81	5.2 / 113.04	0.0028 / 116.67	119

RESULTS AND DISCUSSION

On the 14th day of registration, the germination energy of seeded strawberry seeds processed with a low-frequency pulsed magnetic field exceeded the control values.

The confidence interval was calculated using the formula:

$$\delta_{min-max} = \mu \pm \frac{\sigma}{\sqrt{n}} \times \Phi^{-1} \quad (1)$$

where: $\delta_{min-max}$ – ower and upper limits of the confidence interval; μ – sample average; σ –standard deviation for the sample (unbiased); n –sample size; ϕ^{-1} – inverse function of the standard normal distribution

The obtained values of the mathematical expectation of the energy of germination and germination within each batch are within confidence intervals, which indicate the reliability of the values obtained.

The graphs obtained as a result of the analysis of the obtained results are presented in Figs 3–6.

The results of these studies showed that the value of energy of germination of seeds irradiated by a pulsed magnetic field was changed from 29 to 47%, germination from 34 to 48%. The max. value of the increment of germination of irradiated seeds compared to control sample was 14%.

Energy of germination of the seeds affects both the frequency and the signal ratio of the irradiation and the exposure time. The highest value of their germination corresponds to the frequency of exposure to 16 Hz and the exposure time is 360 seconds. A further increase in exposure time and frequency of exposure led to reduced germination energy by 5%.

Measurements of sprouts showed that processing of seeds electromagnetic field had a positive effect not only on germination but also on the growth of plants. Based on the results of this experiment we can conclude a conclusion about positive influence of low frequency pulsed electromagnetic fields on the qualitative characteristics and the linear parameters of the seeds of the strawberries. Based on the results of this experiment we can conclude a conclusion about positive influence of low frequency pulsed electromagnetic fields on the qualitative characteristics and the linear parameters of the seeds of the strawberries.

The linear parameters of seedlings on the 25th day after seed processing of pulse magnetic field are shown in Table 2.

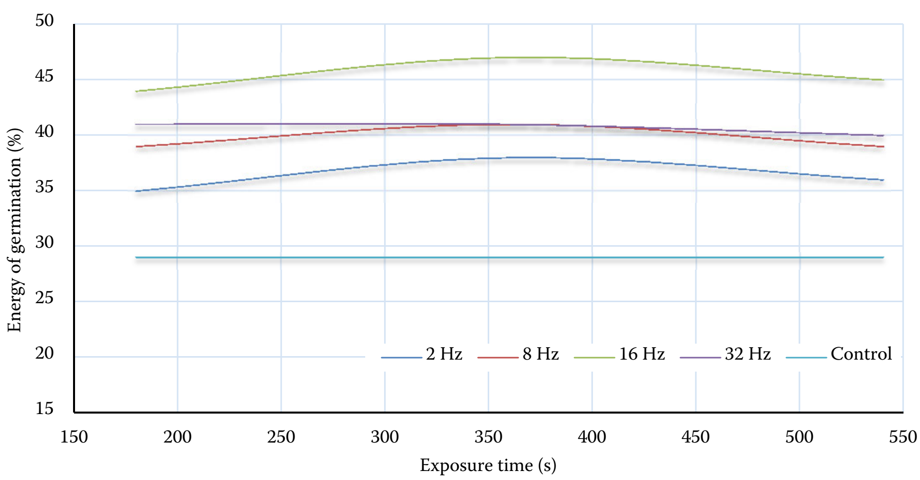

Fig. 3. Energy of germination depending on exposure time and frequency and duty cycle of irradiation

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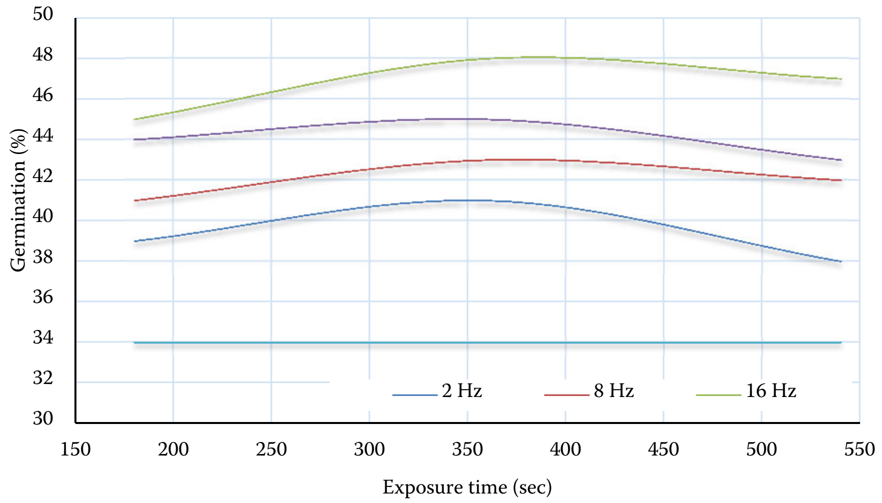

Fig. 4. Germination depending on the exposure time and frequency and the signal ratio of irradiation

As a result of the study it was found that the mechanism of the action of a pulsed magnetic field on strawberry garden is based on the establishment of EMF in individual cell structures, on the shift of equilibrium in biochemical reactions. The direct participation in all chemical reactions in the seeds is taken by water. Due to the change in the normal component of the ion velocity during magnetic processing, the kinetic energy of the relative motion of the particles changes. The molecules act on the force,

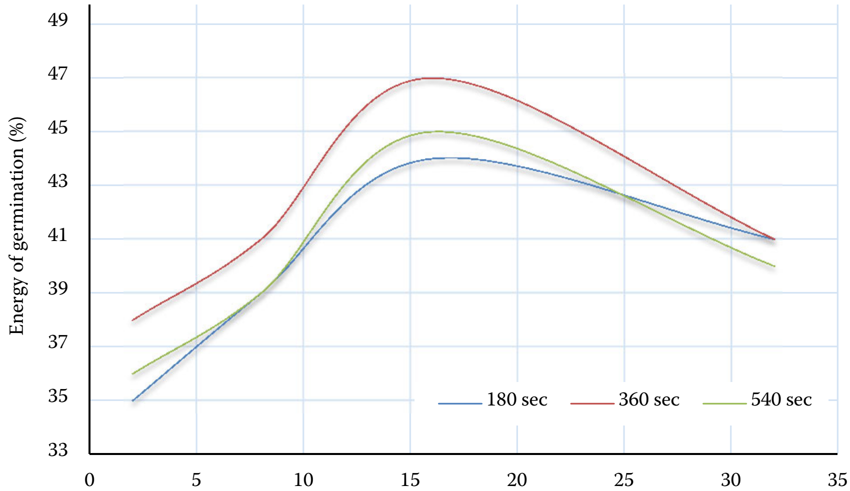

Fig. 5. Influence of irradiation frequency on germination energy

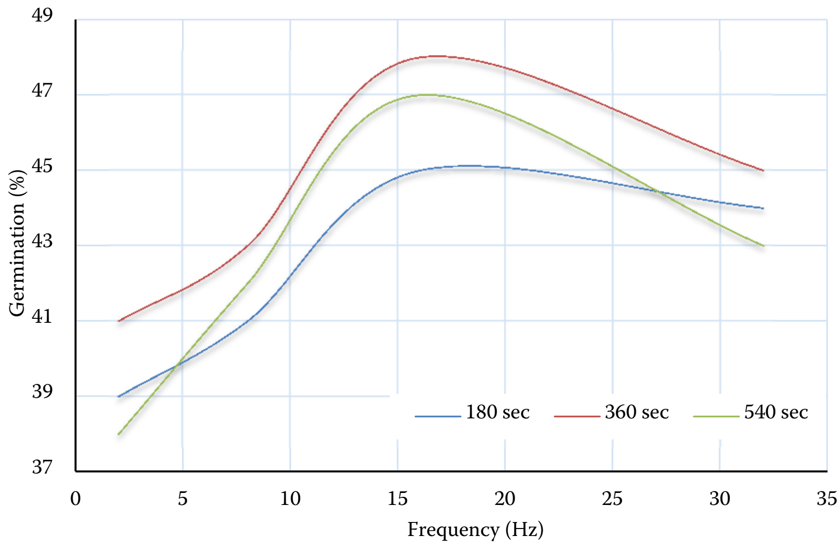

Fig. 6. Influence of irradiation frequency on germination

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which leads to deformation of the cell membrane, as a result of which the diffusion coefficient and the rate of the chemical reaction change. The permeability of the cell increases, the transport of ions accelerates, the concentration of mineral elements increases, resulting in the stimulation of seed development. The positive effect of processing with a pulsed magnetic field was manifested on linear seedlings as follows: the average root length in the experimental version of 16 Hz, 360 s, compared with the control was more by 24%; height of sprouts is more by 28.2%. The increase in the biometric parameters of the strawberry shoots affected their weight, compared to the control it increased by 33.3%.

CONCLUSION

The positive effect of processing seeds of berry crops with a pulsed electromagnetic field of low frequency by the MPP apparatus was experimentally obtained. According to the results of the study, the following conclusions can be drawn:

The highest germination and germination energy value corresponds to a 16 Hz irradiation frequency, a signal ratio of 16 and an exposure time of 360 s with induction in the irradiation zone equal to 5 mT.

The number of seedlings germinated from the processed seeds significantly exceeded the benchmarks.

The increment in the germination of irradiated seeds was 14%, as compared to the control sample, which confirms the positive effect.

Linear parameters of the seedlings increased significantly on the 25th day and exceeded the control parameters by 28%.

The conducted researches have shown the possibility of using pulsed electromagnetic field of low frequency for improving the quality of seeds of berry crops and the efficiency of applying the technology of pre-sowing seed treatment with an electromagnetic field.

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