Experimental studies results of electromagnetic field effect of dielcometer system to increase the yield of greenhouse crops

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Abstract. The article presents experimental studies of the application of electromagnetic technologies for impact on biological objects. Tomato seeds were chosen as experimental biological objects. For the study, the technological parameters of EMF were obtained using the method of full factor experiment. Laboratory and field studies were carried out. In laboratory studies, the results of EMF effects on chromosomal aberrations of tomato seeds were obtained. Dependencies of chromosomal aberrations in tomato seeds on changes in seeds EMF exposure, EMF frequency, and EMF power flow density were given. In field studies, pre-sowing treatment of tomato seeds with electromagnetic radiation was performed in order to cause changes in biochemical processes in the plant. During the experiment, 55 options of pre-sowing EMF treatment with specified parameters were obtained. Dependencies of tomato seed germination on input parameters - EMF frequency, power flow density and exposure were given. After laboratory and field tests, it was concluded that pre-sowing EMF treatment of tomato seeds with optimal parameters results in an increase in chromosomal aberrations of tomatoes by 5.5%; field germination of tomatoes by 18%.

1 Introduction

The study of dielectric properties of seeds and soil depending on temperature, humidity, when exposed to electromagnetic energy, allows to determine the modes of tillage, depth of seeding, optimal EMF parameters in seed processing [1, 2].

Quantitatively, the result of microwave EMF impact is mainly determined by the values of electro- and thermophysical seed properties, which correlate fairly well with their initial humidity within defined limits. In addition, it should be borne in mind that the biological effects of protective reactions depend on the amounts of threshold and resonance values of the object under consideration's parameters, that is, the effect can be reached only when certain levels of microwave EMF exposure have been attained [3, 4].

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2 Materials and methods

Creation of electromagnetic technology to increase the yield of greenhouse plants requires determination of EMF parameters for pre-sowing treatment of seeds.

In accordance with the experimental studies' purpose, we will define the main tasks of the study: the use of the dielcometer system to register the response of greenhouse seeds to the electromagnetic impact; laboratory studies with greenhouse seeds to determine the optimal parameters of EMF causing increased yield and quality; production testing on pre-sowing seeds treatment of greenhouse crops treated with EMF of millimeter range. "Rinato" tomato seeds were chosen as experimental biological objects.

To obtain the EMF technological parameters, the method of full factor experiment was used, the production of which is reduced to the choice of optimization parameter [5]; determination of the list of factors, influencing the plant body; choice of mathematical model; preparation of matrices of experiment planning; calculation and evaluation of regression coefficients significance; validation of model adequacy.

Sowing qualities of the received batch of seeds are as follows: germination (GOST 12038-84) — 96%, frequency (GOST 12037-81) — 98.1%, moisture (GOST 12041-82) — 12%; weight of 1000 seeds (GOST 12042-80) — 42.6 g. In terms of purity and germination, this seed material belongs to class 1. Research was carried out in the climate-thermolight chamber Biotron — 3. Conditions of stationarity and ergodicity of the random process were provided by high technological characteristics of the climate-thermolight chamber, its reliable operation and allowed processing the experiments' results on one implementation.

The ratio of dielectric permeability of irradiated seeds to unirradiated seeds was used as the output parameter — the response function of seeds. Seeds with 40% moisture were used in the experiment.

EMF frequency, power flow density and exposure were used as input controlled parameters.

The factors values and their variation intervals are given in Table 1 for "Rinato" tomato seeds.

Table 1. Factor values and their intervals for "Rinato" tomato seeds.

Variation interval and factor level	Frequency, GHz	Power flow density $\mu\text{W}/\text{cm}^2$	Exposition, sec.
	x_1	x_2	x_3
Zero level $-x_i=0$	40	20	120
Variation interval - λ_i	5	5	10
Upper level $-x_i=+1$	45	25	130
Lower level $-x_i=-1$	35	15	110

The polynomial used to describe the process in this plan is as follows:

$$Y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_2^2 + b_{22}x_2^2 + b_{33}x_3^2 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{23}x_2x_3 \quad (1)$$

where: Y is the output parameter;

x_1 — factors determining process passes (input parameters);

b_0, b_i, b_{ij}, b_{ii} empirically determined coefficients of the regression equation.

When using the standard method of second-order plans construction, matrices of planning of the experiment, calculation of regression coefficients, determination of adequacy and results of processing data were composed.

After measurements and calculations, the regression equation for tomato seeds was obtained:

$$U=1.36+0.24x_1+0.2x_2+0.12x_3+0.16x_1x_2+0.08x_1x_3+0.04x_2x_3+0.08x_1^2+0.02x_2^2+0.02x_3^2 \quad (2)$$

where U is the response of tomato seeds (ratio of electromagnetic radiation irradiated seeds to unirradiated)

$U_{\varepsilon_1'}/\varepsilon'$, where ε_1' is irradiated seeds ; ε' — unirradiated seeds.

Validation of the regression coefficients significance was carried out at the value of $\xi=0.01$ according to the Student criterion [5]. All the coefficients in equation (2) turned out to be significant. Based on the verification of equation data (2) for adequacy according to Fisher criterion [4] it is concluded that the equations describe the real process and therefore allow to estimate the nature of the influence of each factor on response function. To find optimal points of the process, the system of equations was solved, which was obtained by equating zero values of gradient components calculated by the expression

$$\frac{dy}{dx_1} = b_1 + 2b_u + \sum_{j=1}^n b_{ij}x_j = 0 \quad (3)$$

where: x_i, x_j is the coded value of the factor by which the derivative is taken and interacting accordingly with it;

b_i, b_{ii}, b_{ij} are the coefficients of the regression equation.

After differentiation, equations for tomato seeds were obtained:

$$\begin{aligned} \frac{dY}{dX_1} &= 0,24 + 0,16X_2 + 0,08X_3 + 0,16X_1 = 0; \\ \frac{dY}{dX_2} &= 0,2 + 0,16X_1 + 0,04X_3 + 0,04X_2 = 0; \\ \frac{dY}{dX_3} &= 0,12 + 0,08X_1 + 0,04X_2 + 0,04X_3 = 0. \end{aligned} \quad (4)$$

Solutions of the system of equations (4) give the following factors at an extreme point: $X_{1s} = -1.0$; $X_{2s} = 0$; $X_{3s} = -1.0$.

In order to determine the optimal conditions of the studied process (pre-sowing treatment of tomato seeds with electromagnetic radiation), the obtained equation of the second degree (2) was investigated on the extremum [5]. For this, equation (2) has been brought to the canonical species:

$$Y - Y_c = Q_1Z_1^2 + Q_2Z_2^2 + Q_3Z_3^2 \quad (5)$$

where $Q_1 = 0.57$, $Q_2 = -0.537$, $Q_3 = -0.029$ are the roots of the characteristic equation:

$$Q^3 + \alpha Q^2 + \beta Q = 0; \quad (6)$$

$Y_s = 1.18$ — value Y_s at extreme point.

Here $\alpha = -0.12$; $\beta = -0.012$; $\gamma = 0.0002$ are the coefficients determined from the parameters of the regression equation (2) [5]. As a result of conversions of old coordinates to new coordinates [5], factors were obtained at the optimal point: $X_{1op} = 0.044$; $X_{2op} = 0.4$; $X_{3op} = 0.8$, which corresponds to such values of natural parameters: EMF frequency 42.2 ± 0.1 GHz; power flow density $22 \pm 2 \mu\text{W}/\text{cm}^2$; seed irradiation time 128 ± 2.0 s.

3 Results and discussion

Applying electromagnetic radiation to pre-sowing seed treatment is a method of induced mutagenesis. With optimal combination of EMF technological parameters, its effect on plant seeds can unrecognizably change the plant, make it precocious, force to drop leaves and flowers at a certain time, change the color of flowers and fruits, adjust the quality and quantity of protein, its amino acid composition.

Electromagnetic radiation induced mutagenesis allows to create a variety of breeding material in quite a short time and opens up great possibilities of targeted impact on metabolism of seeds and plants. To clarify the modes of pre-sowing seeds treatment by electromagnetic radiation, EMF influence degree estimation methods on the processes of the cell and the whole body metabolism are necessary [6 — 9].

Effect of electromagnetic radiation of the millimeter range on chromosomal aberrations of tomato seeds

The study of the chromosomal aberrations' nature is the most important type of variability, because the violation of the cell chromosomal apparatus is one of the most frequent essential intracellular reactions to exposure to physical factors of electromagnetic nature.

“Rinato” tomato seeds were treated with EMF parameters: frequency range 39-45 GHz, power flow density 17 $\mu\text{W}/\text{cm}^2$, 22 $\mu\text{W}/\text{cm}^2$, 27 $\mu\text{W}/\text{cm}^2$ and exposition 118 s, 128 s, 138 s. The EMF-treated tomato seeds were then germinated in the thermostat on wet filter paper at a temperature of 28°C for two days. After sprouting, the tips of the roots were fixed in vinegar solution for 24 hours and placed in alcohol with 70°C proof. The staining of the root tips was carried out according to the method of C. G. Captar'. After staining, preparations were made for root meristem of sprouts. The preparations obtained were studied with the microscope MBI-15U4.2. The study of chromosomal rearrangements was studied at the anaphase stage or early telophase stage. Under the microscope, 500 to 800 cells in each experiment option were viewed.

Figure 1 presents the results of chromosomal rearrangements under EMF influence of millimeter wavelength range in “Rinato” tomato seeds.

Fig. 1. Percentage of tomato seeds chromosomal rearranging with EMF of power flow density 22 $\mu\text{W}/\text{cm}^2$ and exposure 128 s (I - EMF frequency 39.2GHz, II - EMF frequency 42.2GHz, III - EMF frequency 45.2GHz).

Processing of “Rinato” tomato seeds with EMF was carried out at frequencies of 39.2GHz, 42.2 GHz and 45.2 GHz with a power flow density of 22 $\mu\text{W}/\text{cm}^2$ and an exposure of 128 s. The results of the experiment showed that chromosomal seed aberrations

at 39.2GHz are 5.8%, at 45.2GHz it is 6.2%, and at 42.2 GHz it is $11.3 \pm 0.01\%$. In control seeds, chromosomal aberrations did not exceed the value of $2.6 \pm 0.01\%$.

Figure 2 shows the dependence of chromosomal aberrations in tomato seeds on EMF exposure changes of seeds.

Fig. 2. Percentage of chromosomal seed rearranging with EMF 42.2 GHz and power flow density of $22 \mu\text{W}/\text{cm}^2$.

In an experiment with “Rinato” tomato seeds, it was found that changing the EMF irradiation exposure of seeds from 128 s to 138 s or more does not result in significant changes of chromosomal rearrangements and on average equals to 11.3%. When exposure decreases to 118 s, chromosomal aberrations decrease to 4.5%. In control, chromosomal aberrations in “Rinato” tomato seeds do not exceed the magnitude of 2.6%.

The change in chromosomal rearrangements in the “Rinato” tomato seeds depending on the EMF power flow density change is given in Figure 3.

Fig. 3. Percentage of tomato seeds chromosomal rearranging with EMF at 42.2 GHz and exposure of 128 s.

Tomato seed irradiation was carried out with EMF at 42.2 GHz frequency with a change in power flow density from $17 \mu\text{W}/\text{cm}^2$ to $27 \mu\text{W}/\text{cm}^2$ and exposure 128 s. When EMF power flow density changes within the specified limits, chromosomal aberrations of tomato seeds varied by less than 1%. The difference in chromosomal aberrations between experiment and control of tomato seeds was 8.8%.

Field germination of tomato seeds

Treatment of greenhouse crop seeds by electromagnetic irradiation causes induced mutagenesis of plants, which is associated with changes in biochemical processes in them. The changes occurring in the seeds of greenhouse crops, after exposure to EMF is especially reactive in field germination.

Electromagnetic irradiation was used for pre-sowing treatment of “Rinato” tomato seeds, the technological parameters of which are given in Table 2

Table 2. EMF parameters for seed irradiation

Name of culture	Seed irradiation frequency, GHz	EMP Power Flow Density, $\mu\text{W}/\text{cm}^2$	Exposure of seed irradiation, s
Tomato seeds “Rinato”	39.2; 42.2; 45.2	17; 22; 27	118;128; 138

55 variants were obtained during the experiment. In each variant, 100 tomato seeds were treated with electromagnetic radiation. The sowing was carried out two days after the EMF irradiation of tomato seeds. The experiment used three-row plots, ten seats each, with the sowing of 3 seeds per seat.

EMF untreated tomato seeds served as the control. Results of field seed germination records were processed statistically according to Dospekhov [10].

In the tomato seed experiment, germination was maximum at 42.2 GHz and was 88% for exposure of 128 s and power flow density 22 $\mu\text{W}/\text{cm}^2$. In control, germination was 67%.

Fig. 4. Germination of tomato seeds treated with EMF with power flow density 22 $\mu\text{W}/\text{cm}^2$ and exposure 128 s (I - EMF frequency 39.2GHz, II - EMF frequency 42.2GHz, III - EMF frequency 45.2GHz).

Germination of tomato seeds treated with EMP at 39.2 GHz and 45.2 GHz differed from control by 3%, and the germination value of seeds at 42.2 GHz - by 18%.

Germination of “Rinato” tomato seed from the EMF irradiation time is shown in Figure 5.

Fig. 5. The dependence of tomato germination on the irradiation time at EMF frequency of 42.2 GHz and power flow density of 22 $\mu\text{W}/\text{cm}^2$.

From the given experiment it follows that the EMF treatment of tomato seeds with exposure of 128 s and 138 s almost did not change seed germination and was 88 -89%. Reducing the irradiation time of tomato seeds to 118 s leads to a difference in germination relative to control by only 3%.

4 Conclusions

Laboratory and field studies have shown that pre-sowing treatment of “Rinato” tomato seeds with EMF at optimal parameters results in an increase over control: chromosomal aberrations of tomatoes - 5.5%; field germination of tomatoes - by 18%.

As a result of the obtained data, it was determined that in experimental plants the diameter of stem and fruit is greater compared to the control by an average of 10%, water absorption capacity with the same soil parameters (chemical composition, moisture, temperature) was above 15%. This fact indicates that there is an acceleration of metabolic processes in plant bodies grown from activated seeds. Table 3 shows the yield structure of “Rinato” tomatoes

Table 3. The yield structure of “Rinato” tomatoes

Type of greenhouse culture	Number of pestle flowers, pcs			Yield kg/m ²		Crop increase relative to control	
	total per plant	on the main shoot	on side shoots	control	experiment	kg/m ²	%
Control, tomato “Rinato”	14.2±1.0	6.8±0.6	7.4±0.5	285	355	70	24.6
	42.6±0.9	19.2±1.0	23.4±1.1				

From the results of tomato yield (Table 3) it follows that pre-sowing treatment of tomato seeds with EMF at optimal parameters increases the yield of tomatoes in relation to control by 24.6%.

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