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Study of the effectiveness of combined electrophysical influence on tomato seeds

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Abstract. The paper presents the results of experimental studies on the combined pre-sowing treatment of the tomato seed material of a tomato variety "Malva", which consisted of exposure to visible radiation in the range from 460 to 625 nm and an alternating magnetic field with induction from 6.5 to 65 mTl. Experimental studies were conducted at all stages of plant development: from pre-sowing seed treatment to the final products (tomatoes). As a result of the experimental studies, we revealed that the best results obtained about the dry matter content in tomato seedlings and about the yield on the root of the final products (tomatoes) are achieved at presowing seed treatment with two influencing factors. The first is optical radiation with a wavelength of 460 nm and treatment time of 60 s. The second is magnetic field with an induction of 39 mTl and treatment time of 30 s. After such combined treatment, the seeds were cured for 120 hours before sowing. As a result, we experimentally recorded that the dry matter content in tomato seedlings increased by 25.41%, and the tomato yield increased by 38.00%, compared to the control variant. This allows us to speak about such seed treatment before sowing as an effective agro-technological method, which can be recommended for use in vegetable growing.

Key words: pre-sowing electrophysical treatment, visible radiation, magnetic field, exposure dose, dry matter content, yield.

1 Introduction

Pre-sowing seed treatment is the most important event in the system of agro-technological operations in the cultivation of various agricultural crops. It is aimed at increasing the germination energy, increasing germination, accelerating the growth and development of agricultural plants, increasing the amount of final harvested products. Special attention is paid to the research of electrophysical methods of pre-sowing treatment, the advantages of which are technological efficiency, environmental safety, minimal energy consumption, ease of implementation and practicality, lack of negative impact on the final product. Today, the electrophysical factors affecting seeds have various manifestations, which include: electric and magnetic field; corona and pulse electric discharge field; ionised gas-air medium; electroactivated water solutions; infrared, ultraviolet, monochromatic, coherent radiation, etc. [1–8].

Researchers have recently become scientifically interested in the effects based on the combination of different methods of pre-sowing treatment, for example, such as a combination of irradiation of seeds with different spectra of visible radiation and their treatment in a magnetic field [9].

The purpose of the presented research is to study the combined pre-sowing treatment of the tomato seed material of the tomato variety "Malva" with visible radiation in the wavelength range from 460 to 625 nm and alternating magnetic field with a magnetic induction value from 6.5 to 65 mTl.

2 Materials and methods

The sequence of the experimental research involved four stages.

The first stage was conducted in the research laboratory of the department "Operation of power equipment and electrical machines" of the Azov-Black Sea Engineering Institute, a branch of FGBOU VO Donskoy GAU. And it consisted in the initial treatment of the tomato seed material of the variety "Malva" with monochromatic radiation having different exposures in the wavelength range from 460 to 625 nm; after that, it was done by alternating magnetic fields with the magnetic induction from 6.5 to 65 mTl, and finally by their combinations [10–13].

A laboratory-research complex was used to treat tomato seeds with monochromatic radiation, the structure of which is shown in Figure 1 consisting of a working chamber (1) in the form of a cylinder with a reflective coating of the inner surface (2), a platform for placing treated seeds (3), interchangeable LED matrices

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(4), allowing obtaining required spectra of visible radiation, power supply (5) and a timer (6).

Based on earlier studies [10–12], it was concluded that it is necessary to investigate the use of matrices emitting visible light in the monochromatic ranges of blue, green, and red spectra.

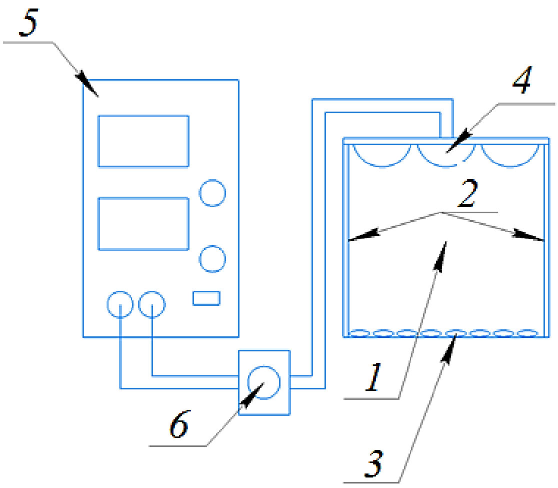

Figure 1. Research complex for seed pre-sowing treatment with monochromatic radiation

Characteristics of light-emitting diodes used in exchangeable irradiation matrices, which showed, as a result of preliminary experimental studies, the best results on pre-sowing stimulation of tomato seeds by monochromatic irradiation. We decided to use it when studying the effect of combined pre-sowing treatment of seeds, shown in Table 1.

Table 1. Characteristics of light-emitting diodes by spectral composition

Spectrum name	Power, W	Wavelength, nm	Rising current, mA	Input voltage, V	Luminous flux, Lm
Blue	3	460–465	700	3.2–3.6	30–40
Green	3	515–520	700	3.2–3.6	60–70
Red	3	620–625	700	2.4–2.6	140–160

Pre-sowing treatment consisted of the following. Seeds were placed in a single layer on the irradiating surface. The power of the light flux of the LED matrix was regulated by the power supply unit 5 by changing the supply current. And the required treatment exposure was set using the timer 6. Therefore, the required dose of energy exposure was provided according to the research programme (Table 2).

Table 2. Dependence of the optical radiation exposure dose on irradiation time (exposure)

LED matrix power P, W	27				
Light spot area S, cm^2	56.2				
Exposure t, s	20	60	120	150	210
Specific energy dose D, W-s/cm^2	9.55	28.66	57.66	71.65	93.55

After the seeds were treated with optical radiation, the seeds were exposed to an alternating magnetic field. The required value of exposure was set using a timer 6, and the induction value was calculated depending on the current flowing in the coil of the magnetic field generator.

The second stage was conducted on the basis of an agro-technological laboratory, where in the course of the experiment, in accordance with current standards, we determined the germination energy and germination of tomato seeds of the variety "Malva". Germination energy was determined on the 5th day, and germination on the 10th day.

The third and fourth stages were carried out in production conditions at the greenhouse farm "Ivanov A.P." in Egorlyksky district, Rostov region.

At the third stage, tomato seedlings were grown from treated seeds in a 50 m² seedling greenhouse. Comparative analyses of the seedlings grown from treated seeds with control samples, which were not treated, were carried out according to standard methods for several parameters, such as leaf area, dry matter mass of vegetative and root parts [14–15].

The fourth stage of experimental research was carried out in a production greenhouse with an area of 200 m², in which experimental blocks of one hundred bushes occupied an area of 17.6 m² each (Fig. 2). Planting seedlings in the production greenhouse to determine the yield was carried out on the 43rd day after pre-sowing treatment, and the yield was determined on the 44th day after transplanting the seedlings into the ground.

Fig. 2. Tomato plants in the production greenhouse in the process of crop ripening

To determine the yield, one of the four methods of yield determination was used, i.e. the method of determining the yield on the root [16], which is calculated by the weight of fruit after harvesting the entire crop. In this case, it was necessary to know the area of 100 bushes from which the crop was harvested. After that, the calculation was carried out according to the formula:

$$U_r = Y/S, \quad (1)$$

whereU_r – yield on the root, kg/m²; Y – yield, kg; S – area of 100 bushes, m².

3 Experimental results and their discussion

The effectiveness of combined pre-sowing seed treatment, carried out sequentially, first by optical radiation and then in a magnetic field, can be judged by the yield of plant dry matter mass during seedling growth and by the yield at the root during final production [17–19].

Table 3. Biometric indices and dry matter content of tomato plants of the tomato variety "Malva"

Treatment options	No. n/a	Exposure doses: Optical radiation D, Watt-s/cm²	Exposure doses: Magnetic field W, Tl-s	Leaf area, cm /pc²	Dry matter content of vegetative part, %	Root dry matter content, %	Dry matter content of the plant, %	Increase in dry matter content in relation to the control variant,+/-, %
Control		-	-	21.17	51.14	13.7	41.81	-
Optical radiation	1	9.55	-	22.21	50.45	14.18	45.3	+3.49
	2	28.66	-	27.92	67.62	24.91	55.21	+13.40
	3	57.32	-	26.13	67.40	23.92	55.00	+13.19
	4	71.65	-	24.56	57.18	22.3	54.63	+12.82
Combined treatment	5	9.55	0.43	21.13	50.13	11.98	41.20	-0.61
	6	28.66	0.43	25.00	68.02	12.76	44.60	+2.79
	7	57.66	0.43	25.88	65.00	15.08	45.13	+3.32
	8	71.65	0.43	26.11	64.11	15.0	60.80	+18.99
	9	9.55	1.28	26.68	69.20	17.9	57.01	+15.20
	10	28.66	1.28	26.90	73.10	18.66	57.22	+15.41
	11	57.66	1.28	27.96	68.93	19.07	64.16	+22.35
	12	71.65	1.28	28.40	66.04	17.33	63.43	+21.62
	13	9.55	3.86	28.12	72.51	20.76	56.88	+15.07
	14	28.66	3.86	28.59	76.44	25.5	66.03	+24.22
	15	57.66	3.86	29.06	75.13	24.01	67.22	+25.41
	16	71.65	3.86	28.71	70.86	20.99	63.70	+21.89
	17	9.55	6.44	24.90	63.01	18.32	59.20	+17.39
	18	28.66	6.44	26.34	65.30	20.3	61.74	+19.93
	19	57.66	6.44	25.77	65.09	17.81	61.13	+19.32
	20	71.65	6.44	24.09	61.18	17.0	62.80	+20.99
Magnetic field	21	-	0.43	27.55	64.31	20.52	60.91	+19.10
	22	-	1.28	27.98	68.60	25.43	62.44	+20.63
	23	-	3.86	28.64	73.85	17.64	62.57	+20.76
	24	-	6.44	25.22	73.40	17.98	60.12	+18.31

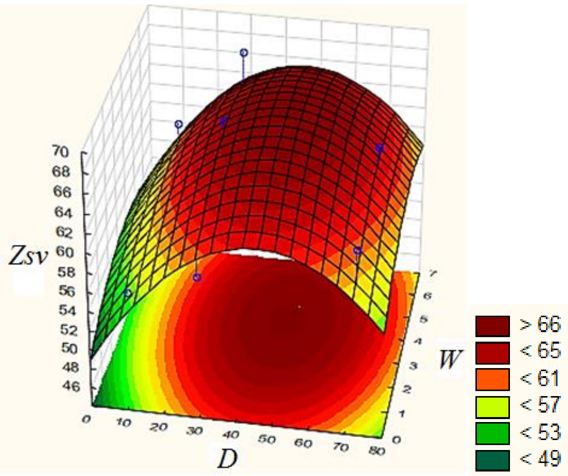

Fig. 3. Response surface showing how the combination of energy doses to tomato seeds affects seedling dry matter content ($\boldsymbol{Z_{sv} = f(D;W)}$)

To identify the optimal parameters of seed pre-sowing treatment, a response surface was constructed (Figure 3), showing how the combination of doses of energy influence on tomato seeds affects the dry matter content of seedlings. The regression equation describing this effect is as follows:

$$Z_{sv} = 62.96 + 0.436D - 4.262W - 0.21DW - 0.0066D^2 + 0.736W^2 + +0.023DW^2 + 0.004D^2W - 0.00058D^2W^2 \quad (2)$$

The optimisation problem that was posed in the study is solved by constructing the desirability response function [14]. The optimal levels of parameters (Fig. 4) are shown on the graphs by red lines and tend to 1 (very desirable parameter). As a result of analysing the graphical functions of the optimal profile figure, the optimal parameters of doses of combined energy exposure (D=55.057 W-s/cm², W=3.43 Tl-s) were determined to obtain the maximum dry matter content in seedlings [20].

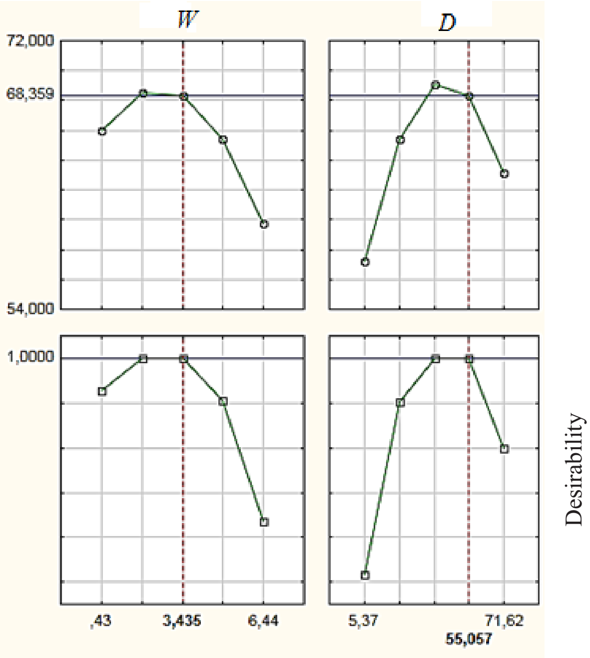

Fig. 4. Desirability response function for the equation showing the effect of doses on seedling dry matter content $\boldsymbol{Z_{sv}} = \boldsymbol{f(D, W)}$

The root yield experiment was conducted in two main production periods: the first was the spring-summer period and the second was the summer-autumn period [21].

The analysis of histograms presented in Figure 5 allows us to conclude that all variants of pre-sowing treatment give an increase in the yield compared to the control variant. But the best result is achieved during combined treatment with monochromatic radiation with the following parameters. Optical radiation wavelength is λ=460 nm, exposure of optical radiation treatment is t=60 s and treatment in magnetic field with magnetic field synduction of B=39 mTl, treatment time is t=30 s. It is also important to note that during the study, such parameter as the time of seed curing before sowing was recorded, so in the optimal mode this time was T=120 hours [22].

Pre-sowing treatment with these parameters, increased the yield on the root by 37.9% in the spring-summer period and by 38.0% in the summer-autumn period, compared to the control variant [23, 24].

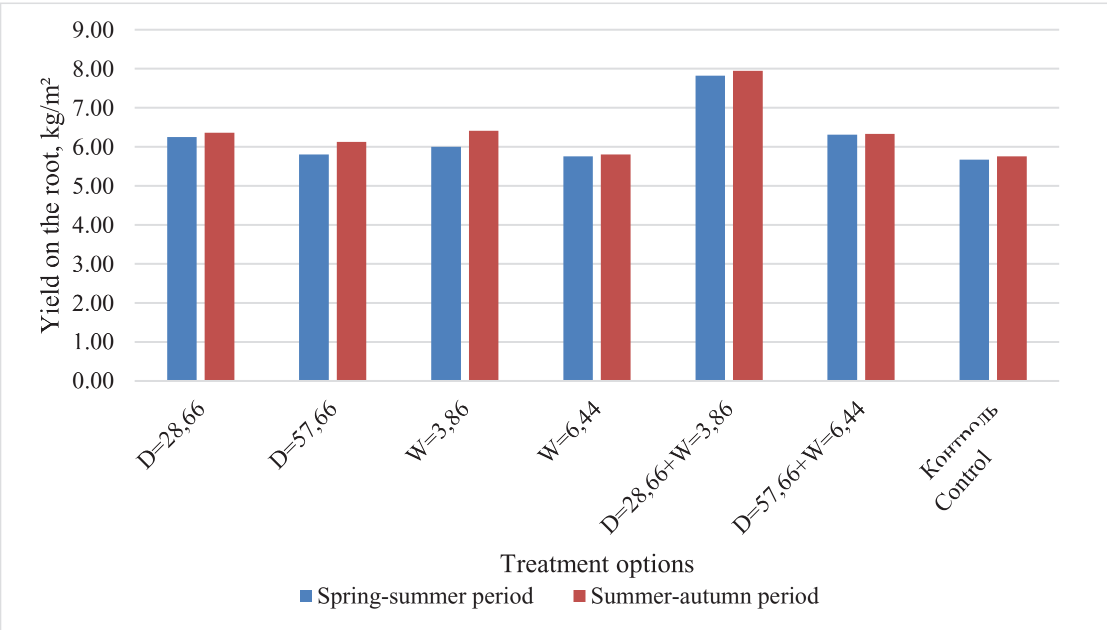

Fig. 5. Distribution of the yield on the root depending on variants of seed pre-sowing treatment and a seasonal period of the year

4 Conclusions

As a result of experimental studies, we determined that the best results in terms of dry matter content in tomato seedlings and yield on the root of final products (tomatoes) were achieved with the following parameters of combined pre-sowing treatment of seeds. The first is optical radiation with a wavelength of 460 nm and exposure treatment of 60 s. The second is magnetic field with an induction of 39 mTl and treatment time of 30 s. After this treatment, the seeds were cured for 120 h before sowing. The dry matter content in tomato seedlings increased by 25.41%, and the tomato yield increased by 38.00% compared to the control variant.

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