Results of studies on the application of UV radiation for disinfecting the surface of soybean seeds from pathogenic microflora

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Abstract. The results of studies on the use of UV treatment for the disinfection of soybean seeds from pathogenic microflora before sowing are presented. The research is devoted to the development of a technology for preparing seeds before sowing, which involves pre-treatment of seeds with UV radiation, followed by treatment with traditional chemical and biological means of protecting seeds from pathogenic microflora. The research was aimed at establishing the relationship between the parameters of UV treatment and the effectiveness of surface disinfection of seeds. The object of experimental studies was the seeds of soybean variety «Nezhegol». The influence of such influencing factors as the energy illumination of the surface under UV irradiation and the duration of UV irradiation was studied. As a function of the response to UV exposure, the total number of microbial cells (CFU/g) after treatment was taken. It has been established that seed treatment with UV radiation provides effective disinfection of the seed surface. The number of microbial cells on the soybean surface after UV treatment decreased by 99% compared to the control. For the disinfection of soybean seeds, it is possible to recommend a treatment mode with an energy illumination of UV irradiation of 9 W/m² and a minimum duration of UV irradiation of 30 s. Specific energy costs for UV treatment range from $1.16 \cdot 10^{-4}$ kW·h/m² to $2.25 \cdot 10^{-4}$ kW·h/m².

1 Introduction

Plant growing is one of the key branches of agricultural production. The development of plants and the quality of the crop obtained are influenced by physical and biological factors. To increase the yield of crops, various types of seed treatment are used before sowing. Such treatment involves the selection of good seeds, pre-sowing stimulation and surface disinfection of seeds. In this case, various methods, technological methods and technical means are used [1-4]. To disinfect and improve the sowing properties of seeds and grain, various physical (electrophysical) effects [5–6] and UV radiation treatment [7–11] can also be used. Electrophysical methods of influencing seeds are effective, but do not completely exclude the use of chemical and biological protection of agricultural plants. The effectiveness of the use of means of chemical and biological protection of agricultural plants decreases over time due to an increase in the resistance (resistance) of microorganisms to the action of chemicals. The consequence of increasing the resistance of microflora to the action of chemicals is an increase in the volumes and doses of drugs to achieve a positive result during

pre-sowing treatment. The effectiveness of disinfection can be increased by using the combined use of chemical and biological protection and electrophysical methods of seed treatment. One of the options for a new technology of seed treatment before sowing can be the use of chemical and biological protection means UV seed treatment [12–13].

This technology involves pre-treatment of seeds with the energy of optical radiation of the ultraviolet spectrum, followed by treatment with traditional means of protection. Preliminary UV treatment of seeds ensures the partial destruction of harmful microflora and a decrease in the resistance of its remaining part.

UV technology can be applied to seeds of various crops. To implement it, it is sufficient to use the existing sources of UV radiation and the applied technologies for the chemical and biological protection of agricultural plants. The scientific task is to develop effective means for UV seed treatment and to determine the optimal irradiation regimes that provide a sufficient level of efficiency.

Below are the results of studies on the use of UV treatment for surface disinfection of soybean seeds from pathogenic microflora.

2 Materials and methods

Experimental studies involved the identification of the relationship between the parameters of UV treatment and the effectiveness of surface disinfection of seeds. Soybean grains of the Nezhegol variety were used as the object of experimental studies.

As the main variable influencing factors in the course of experimental studies, the following were determined: the energy illumination of the surface during UV irradiation and the duration of UV irradiation. The total number of microbial cells (CFU/g) after treatment was evaluated as a response function.

Sample processing was carried out according to Kono's plan for a first-order 2-factor experiment. The coded values and the interval of variation of the influencing factors are given in Table 1.

Table 1. Influence factors.

Designation	Factor name	Levels of variation			Variation intervals
		-1	0	1	
X_1	Energy illumination of the surface under UV irradiation, W/m2	1	5	9	4
X_2	Duration of UV irradiation, sec	30	60	90	30

The research methodology included several stages.

1. Preparation of soybean seed samples for processing.
2. Processing of experimental samples using a DKBU-7 ultraviolet lamp in accordance with the experimental plan.
3. Examination of samples in the testing laboratory of the Belgorod State Agrarian University to determine the total number of microbial cells in accordance with the Russian State Standard (GOST 10444.15).

3 Results

The results of experimental studies are shown in Table 2. In the table, for each point of the UV exposure plan, the values of the total microbial contamination on the surface of the seeds are determined.

The reproducibility of the experiments was evaluated using the Cochran test at a significance level of α=0.05 and the number of degrees of freedom f_2=12. The calculated value of the Cochran criterion G_p=0.37 did not exceed the allowable values $G_{0.05}$=0.68 (0.37≤ 0.68)

The implementation of the Kono plan of the first order for a 2-factor experiment made it possible to obtain a regression relationship between the response function and the influencing factors.

Table 2. Plan matrix and experiment results.

№ experience	X_1	X_2	Total number of microbial cells, 103 CFU/g	LSD_{05}
1	-1	-1	1.8	0.3
2	1	-1	0.4	0.1
3	-1	1	2.0	0.3
4	1	1	0.3	0.1
5	0	0	1.0	0.4
6	control	-	34.0	3.9

The resulting regression equation in coded variables has the form:

$$Y = B_0 + B_1X_1 + B_2X_2 + B_{12}X_1X_2, \quad (1)$$

where X_1 - energy illumination of the surface under UV irradiation, r.u. ($-1 \le X_1 \le +1$) ; X_2 - duration of UV exposure, p.u. ($-1 \le X_2 \le +1$); B_0 = 1.10; B_1 = -0.76; B_2 = 0.03; B_{12} = -0.06 – values of the coefficients of the regression equation.

The calculated regression equation in natural variables is obtained by replacing the coded variables in equation (1) with their natural counterparts in accordance with Table 1 using the formulas:

$$X_1 = \frac{(E_o - 5)}{4}, \quad (2)$$

$$X_2 = \frac{(t_o - 60)}{30}, \quad (3)$$

where E_o is the energy illumination of the surface under UV irradiation, W/m^2;
t_o is the duration of irradiation, s.

The significance of the coefficients was tested using Student's t-test (tst) at a significance level of α = 0.05 and the number of degrees of freedom f_2=12. As a result of the check, it turned out that the coefficient B_2 is less significant compared to the others. The adequacy of the model was assessed by the Fisher criterion at a significance level of α=0.05. The calculated value of the Fisher criterion F_p=1.18 did not exceed the allowable values $F_{0.05}$=4.75 (1.18≤4.75).

4 Discussion

Figure 1 below shows the calculated surface of the total number of microbial cells (CFU/g) on soybean seeds depending on the natural values of the surface energy irradiance during UV irradiation (W/m^2) and the duration of UV irradiation (s).

The decrease in the total microbial contamination on the surface of the seeds, expressed as a percentage compared to the control sample, is presented in table 3.

Table 3. Decreased overall microbial contamination.

№ experience	The value of factors in natural units		Decrease in total microbial contamination compared to control, %	Dose of UV radiation, J/m²	energy costs, J/%
	X_1	X_2			
1	1	30	94.7	30	0.3
2	9	30	98.9	270	2.7
3	1	90	94.3	90	1.0
4	9	90	99.1	810	8.2
5	5	60	97.1	300	3.1

According to the data obtained in the field of changing influencing factors (table 3), there is a tendency to reduce the number of microbial cells on the soybean surface after treatment with an increase in the surface energy illumination under UV irradiation (W/m^2) and the duration of UV irradiation (s).

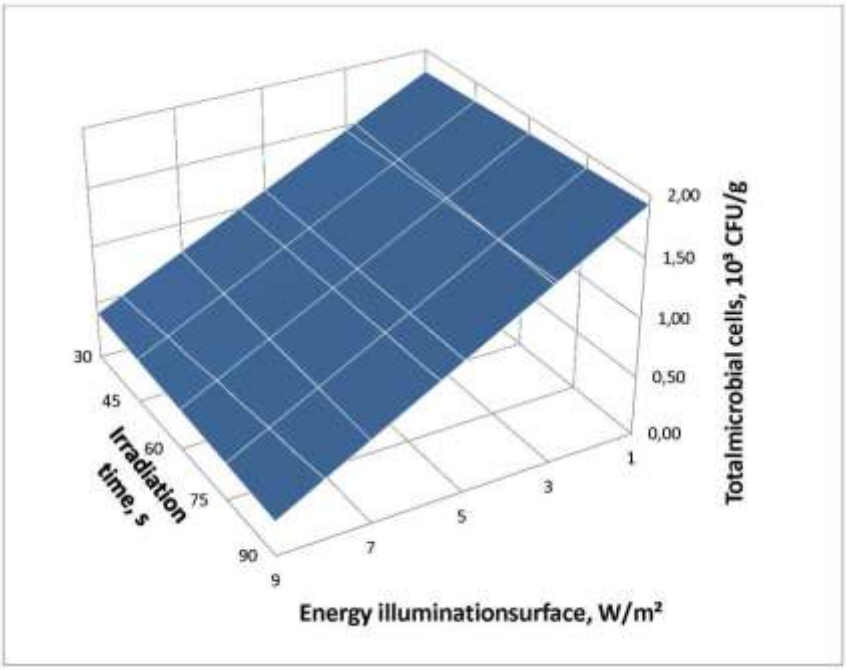

Fig. 1. Change in the total number of microbial cells on the soybean surface depending on the natural values of the surface energy illumination and the duration of UV irradiation.

In this case, the influence of the magnitude of the energy illumination of the surface under UV irradiation is more significant. This must be taken into account when choosing an exposure for disinfection. The maximum efficiency of ultraviolet treatment is observed in modes with a maximum energy illumination of the surface of 9 W/m^2 and treatment duration of 30 and 90 seconds. At the same time, the total number of microbial cells on the soybean surface decreased by 99% compared to the control. Taking into account energy costs, it is expedient to use the regime with energy illumination of the surface of 9 W/m^2 and a processing time of 30 seconds. The treatment dose in this case will be 270 J/m².

The decrease in the total microbial contamination of the seed surface is of particular importance for the production of green vitamin feeds. Among the various microbiological requirements for feed quality, one of the main indicators is the total microbial number (TMC). According to the draft Customs Regulations of the Eurasian Economic Union «On the safety of feed and feed additives», the TMC indicator for pigs, cattle, sheep and goats, horses should not exceed $5 \cdot 10^5$ CFU/g. In the studies carried out, it was possible to achieve a TMF value of $0.3 \cdot 10^5$ CFU/g. The achieved result testifies to the high efficiency of UV treatment.

5 Conclusion

Based on the data presented, the following conclusions can be drawn.
1. Treatment of seeds with UV radiation provides effective disinfection of the surface of seeds. It has been established that it is possible to reduce the total number of microbial cells on the surface of soybeans by 99% compared to the control.
2. It has been established that for production it is necessary to recommend a mode with an energy illumination of UV irradiation of 9 W/m² and a minimum duration of UV irradiation of 30 s.
3. A feasibility study showed that the specific electricity consumption for UV treatment ranges from $1.16 \cdot 10^{-4}$ kWh/m² to $2.25 \cdot 10^{-4}$ kWh/m². The final calculations can be adjusted taking into account the productivity during processing.

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