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S V Vendin

Belgorod State University, 1, Vavilova ave, Maisky settlement, Belgorod region, Belgorod region, 308603, Russia

E-mail: Vendin_SV@bsaa.edu.ru

Abstract. Electric, magnetic and electromagnetic fields can be successfully applied in various processes of agricultural production. To improve the sowing properties, seeds of various crops are subjected to special treatment. Research shows that treating seeds with the energy of electromagnetic fields also increases the germination capacity of seeds. However, the effect of treatment depends on the level of influencing factors. Therefore, it is very important to observe the correct treatment regimes (exposure parameters). The article presents the results of experimental studies to assess the influence of the microwave power intensity and exposure duration onto the sowing properties of lupine seeds. Based on the processing of experimental data, regression equations were obtained that take into account the effect of the magnitude of the specific microwave power of exposure and exposure on the ability of lupine seeds to germinate. The experiment showed that with the help of microwave treatment it is possible to obtain not only the effect of stimulation, but also the inhibition of plant growth. Regimes have been also identified in which seeds are insensitive to microwave treatment. At the same time, modes have been identified in which a stimulating effect manifested itself, as well as areas of insensitivity and negative impact. At the same time, it can be unambiguously asserted that an increase in exposure to microwave exposure is most pronounced at higher values of specific microwave power. Compared to the results of processing wheat seeds, to stimulate lupine seeds, it is necessary to provide higher values of the specific power of microwaves and exposure. The best processing result was obtained at a specific power level of 1.17 kW/kg and an exposure of 60 s. Therefore, this mode can be recommended for pre-sowing microwave treatment of lupine seeds.

1. Introduction

Electric, magnetic and electromagnetic fields can be successfully applied in various technological processes of agricultural production [1-10]. At the same time, the effectiveness of electromagnetic treatment of seeds and grain in the processes of pre-sowing stimulation, disinfection, disinsection, drying, etc. is essentially determined by the processing modes and the initial properties of the seeds. This is due to the fact that biological objects are characterized by protective reactions and the effect can be obtained only when certain levels of parameters of exposure to microwave EMF are reached. As scientific studies related to the use of electromagnetic fields in crop production show, to ensure reliable technological microwave processing, it is necessary to strictly observe the specified levels of specific microwave power of exposure and comply with the requirements for processing (exposure) time, which imposes requirements on the area of recommended technological processing modes. Therefore, to ensure the technological modes of microwave seed treatment, it is important to establish a reliable relationship between the parameters of the microwave EMF, the initial parameters of the seeds and the

biological indicators of the effectiveness of the microwave seed treatment. The significance and influence of the specific microwave power of exposure and the time of treatment (exposure) during seed treatment can be estimated only on the basis of statistical processing of the experimental results with obtaining regression equations (models) of the dependence of the germination ability.

2. Results

Below are the results of experimental studies to assess the effect of the specific microwave power of exposure and the time of treatment (exposure) on the sowing properties of lupine seeds. The aim of the research was to evaluate the effect of microwave treatment on the ability of seeds to germinate. The moisture content of seeds in the experiment was 10.25%. The seeds were treated in a microwave installation of continuous irradiation with a microwave power of 0.5 kW and a radiation frequency of 2450 ± 50 MHz.

For processing, a radio-sealed working chamber was used, which made it possible to exclude the loss of microwave energy into the surrounding space and to increase the utilization rate of the generator. In the course of the experiment, such parameters as the specific microwave power of exposure and the treatment time (exposure) were recorded, and the initial and final temperatures of microwave heating of seeds were measured. After microwave treatment, the seeds were sent for germination. Evaluation of the quality of seed treatment was carried out according to such indicators as germination energy and germination ability (germination).

For the possibility of regression analysis of the experimental results, the processing of the samples was carried out in accordance with the Kono plan for a 2-factor experiment. The coded values and the interval of variation of the influencing factors are given in Table 1. The number of points of the experimental design and the values of the influencing factors are shown in Table 2. Studies in 4-fold repetition in each of the 4 points of the experimental design.

Table 1. Coded and natural values of influencing factors.

Factor name	Factor coded values			Variation interval, Δ
	-1	0	+1	
Specific power, kW / kg, X1	0.83	1.00	1.17	0.17
Exposition, c, X2	40	50	60	10

Table 2. Values of parameters of influencing factors in the experiment according to Kono's plan.

N	Specific power, kW / kg	Exposition, c
1	0.83(-)	40(-)
2	1.17(+)	40(-)
3	0.83(-)	60(+)
4	1.17(+)	60(+)
5	0.83(-)	50(0)
6	1.17(+)	50(0)
7	1.00(0)	40(-)
8	1.00(0)	60(+)
9	1.00(0)	50(0)

The main results of the experiment and indicators of energy and germination ability of lupine seeds are shown in Table 3.

The reproducibility of the experiments was assessed using the Cochran test at the significance level α=0.05 and the number of degrees of freedom $f_2 = 12$. The calculated value of the Cochran test G_{calc} did not exceed the permissible values $G_{0.05}$ (3.9) (0.08≤0.40).

Table 3. Results of treatment of lupine seeds.

N	Specific power P, kW/kg,	Exposure τ, s	Germination ability, %	
			average	Difference with control
1	0.83	40	87.0	+0.5
2	1.17	40	85.5	-1.0
3	0.83	60	86.5	0.0
4	1.17	60	88.0	+1.5
5	0.83	50	84.5	-2.0
6	1.17	50	87.5	+1.0
7	1.00	40	86.0	-0.5
8	1.00	60	87.5	+1.0
9	1.00	50	86.0	+0.5
10	The control		86.5	-

After statistical processing of the data, a regression equation was obtained that describes the effect of the specific microwave power (kW / kg) and exposure (s) on the germination capacity of seeds, which in coded variables has the form:

$$Y = B_0 + B_1X_1 + B_2X_2 + B_{12}X_1X_2 + B_{22}X_2^2, \quad (1)$$

where X_1 is the specific microwave power, p.u. ($-1 \le X_1 \le +1$), X_2 is the exposure, p.u ($-1 \le X_2 \le +1$); B_0 = 86.00; B_1 = 0.50; B_2 = 0.58; B_{12} = 0.50; B_{22}= 0.75.

The significance of the coefficients was checked by the Student's test (t_{cr}) at the significance level α = 0.05 and the number of degrees of freedom f_2 = 27. All coefficients in equation (1) are significant, therefore the factors are sufficiently correlated with each other. The adequacy of the model was assessed by Fisher's criterion at a significance level of α = 0.05. The calculated value of the Fisher criterion F_{calc} did not exceed the permissible values $F_{0.05}$ (5, 27) ($1.69 \le 2.69$).

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:

$$X_1 = (P - 1)/0.17, X_2 = (t - 50)/10, \quad (2)$$

where P is the specific microwave power, kW / kg ($0.83 \le P \le 1.17$); t - exposure, s ($40 \le t \le 60$).
One of the forms of the calculated regression equation in natural variables can be represented as follows:

$$Y = B_0 + B_1\left(\frac{P-1}{0.17}\right) + B_2\left(\frac{t-50}{10}\right) + B_{12}\left(\frac{P-1}{0.17}\right)\left(\frac{t-50}{10}\right) + B_{22}\left(\frac{t-50}{10}\right)^2, \quad (3)$$

3. Process analysis

Figure 1 below shows the calculated surface of the germination ability for lupine seeds, depending on the natural values of exposure time (s) and specific microwave power (kW / kg). The germination ability of the control seeds was 86.5%.

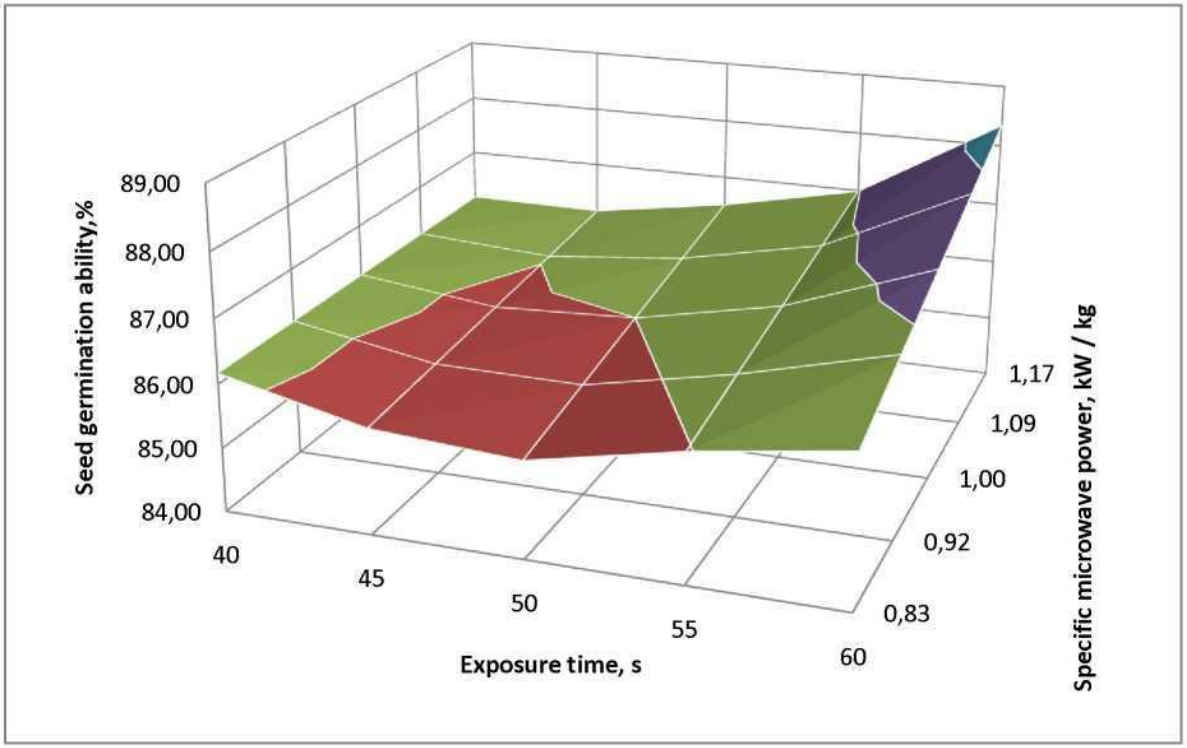

Figure 1. Changes in the germination ability of lupine seeds after microwave treatment.

Analysis of the seed germination surface indicates that the result of treatment is determined by the relationship of both influencing factors. At the same time, modes are observed in which a stimulating effect is manifested, as well as areas of insensitivity and negative impact. According to the data obtained, it can be argued that an increase in the exposure to microwave exposure is most pronounced at higher values of the specific microwave power. Compared with the results of processing wheat seeds [10], to stimulate lupine seeds, it is necessary to provide higher values of the specific microwave power and exposure. Note that the best treatment result (an increase in germination by 1.5% compared to the control) was obtained at a specific power level of 1.17 kW/kg and an exposure of 60 s. Therefore, this mode can be recommended for pre-sowing microwave treatment of lupine seeds.

4. Conclusion

The results of experimental studies on the assessment of the influence of the specific microwave power of exposure and the time of treatment (exposure) on the sowing properties of lupine seeds are presented. Experimental data were used to obtain regression equations in coded and natural variables to assess the effect of the magnitude of the specific microwave power of exposure and exposure on the germination ability of lupine seeds.

It was found that the result of processing is determined by the relationship of influencing factors. The range of values of the studied influencing factors made it possible to identify the modes in which the stimulating effect, oppression and insensitivity to the effect are manifested. At the same time, it can be unambiguously asserted that an increase in exposure to microwave exposure is most pronounced at higher values of specific microwave power. Compared to the results of processing wheat seeds, to stimulate lupine seeds, it is necessary to provide higher values of the specific microwave power and exposure. Note that the best treatment result (an increase in germination by 1.5% compared to the control) was obtained at a specific power level of 1.17 kW/kg and an exposure of 60 s. Therefore, this mode can be recommended for pre-sowing microwave treatment of lupine seeds.

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