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To cite this article: M V Gorelov and T N Bastron 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **315** 052069

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Studying SHF electromagnetic field modes on germinating ability of seeds of coniferous species

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Abstract. Experiments were performed to study the effect of the electromagnetic field of ultra-high frequency on the heating and germinating ability of seeds of coniferous trees. The seeds of Scots pine were investigated. Active planning was applied for the purpose of experiment; Kono-2 two-factor plan, which included 9 experiments, was selected. Parameters like unit specific power and treatment time were changed, when the seeds were irradiated. According to the results of the laboratory experiment, the article presents the data obtained and control tests on the effects of UHF EMF on germinating ability of the pine seeds, technological modes and installation parameters (time and heating power) have been considered. It was established that the mode with power level of 200 W/cm³ and maximum time of 60 seconds had the maximum stimulating effect on the seeds.

1. Introduction

Among the diversity of wealth that nature has endowed the Russian Federation, forest is the most significant one. Under the conditions of intensive export of wood and its deep processing within the country, where there is a tendency to increase the production capacity of wood processing and pulp and paper mills, there is an acute problem of releasing vast areas that require reforestation. Growing seedlings of forest crops in forest nurseries is ensured with seeds. Germinating ability of pine seeds with standard planting is 72-76%. Presowing treatment of seeds, with the help thereof it is possible to protect seeds against diseases and stimulate their effective germination, is one of the conditions to obtain healthy seedlings [1-3]. Existing methods and ways of growing seed material today are lagging behind the world level and require modernization using scientific potential, modern innovative methods and scientific and technical developments, whereas standard material with low germination rates is used to grow seedlings. The study of scientific information shows that the solution to the problem of forests reproduction may refer to the use of electromagnetic and thermal effect of UHF field [4-5]. Due to relative ease of use, this technology can easily be implemented in production process of obtaining seeds with high germination rates and germination energy [6].

The purpose of this study is the possibility and feasibility of using UHF electromagnetic field (UHF EMF) to increase germination in preparation for sowing seeds of coniferous trees.

2. Experiment details

The main research methods were as follows: active experiment planning to identify seed germination regression equations; physical and mathematical modeling to determine dependence of impact of



factors, statistical methods of processing and evaluation of results of experiments (dispersion and regression analyzes); and numerical method.

Model studies to obtain regression equations were performed on an experimental laboratory setup with UHF units. Specific unit capacity and time of seed treatment by electrophysical effects were chosen as parameters being studied for the model. The field of study was limited to permissible values of moisture and temperature of the seeds. Seed heating temperature should not exceed 46 - 48°C. Excessive heating temperature of seeds leads to occurrence of roasted, steamed seeds, and increase in the number of broken and crushed seeds. The initial seed moisture in all experiments was maintained at the level of 20%±2%.

On the basis of reference data, factors and their range of changes given in table 1 were selected from a variety of factors influencing the heating process.

Table 1. Values and variation range for the controlled factors

Controlled factors	Coded value of factors being controlled	Low level	Basic level	Upper level	Variation interval
		-1	0	1	λ_i
Specific power of the unit, W/cm ³	X ₁	80	140	200	60
Time of treatment, sec.	X ₂	60	120	180	60

Dimensional controlled independent factors were transformed into dimensionless, rated Xi (i = 1, 2, ..., m):

$$X_i^{(-)} \leq X_i \leq X_i^{(+)} \tag{1}$$

$$X_i^0 = \frac{X_i^{(-)} + X_i^{(+)}}{2} \tag{2}$$

$$\lambda_i = \frac{X_i^{(+)} - X_i^{(-)}}{2} \tag{3}$$

where $X_i^{(0)}$ — basic level of factors; $X_i^{(-)}$ — lower level of factors; $X_i^{(+)}$ — upper level of factors; λ_i — variation interval.

Active planning was applied for the experiments, and a full factorial experiment was selected. In the case of two independent variables, Kono-2 two-factor plan, comprising 9 experiments (N = 9) has good properties. In the second-order plans, either independent variable should take several, but not less than three values.

The basic methods of research were as follows: active experiment planning to identify seed germination regression equations; physical and mathematical modeling to determine dependence of influence of factors, statistical methods of processing and evaluation of results of experiments (dispersion and regression analyzes); and numerical method. Model studies to obtain regression equations were performed on an experimental laboratory installation with UHF units. For laboratory tests, a flowchart has been developed (figure 1).

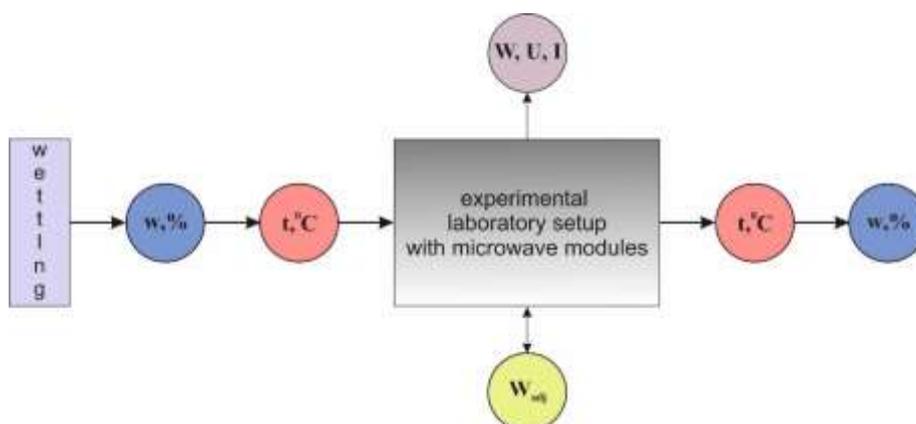


Figure 1. Experiment diagram.

The seeds were moistened for 30 minutes in advance to moisture content of 20% in a solution of micro elements. Solution composition: cobalt sulphate (0.05%), potassium permanganate (0.002%) zinc sulphate (0.02%), and copper sulphate (0.03%). Then batches of 100 seeds were processed in the chamber of UHF unit according to the active planning plan. The experiment was performed with a triple repetition. In every experiment, the temperature was measured with CENTER 310 thermohygrometer with a chromel-copel thermocouple and moisture content of the treated seeds - with Fauna-M moisture meter. Every batch of treated seeds was examined for physical damage. K-505 measuring complex was used to change power consumption, current and voltage at the input of the power transformer.

3. Results and Discussion

The results of observations of the experiment, respectively, and variations of the plan were recorded in the table of analysis of dispersion analysis for each factor in triplicate.

Table 2. Dispersion analysis table.

Experiment No	X ₁	X ₂	Seeds heating temperature				Laboratory-scale germinating ability of the seeds			
			Y ₁₁	Y ₁₂	Y ₁₃	Y _{u1 avg.}	Y ₂₁	Y ₂₂	Y ₂₃	Y _{u2 avg.}
1	1	1	42,7	43,3	43	43,00	85	82	77	81,3
2	-1	1	33,4	35,3	34,2	34,30	98	97	97	97,3
3	1	-1	34,5	36,8	35,2	35,50	87	92	88	89,0
4	-1	-1	28,9	30,1	29,4	29,47	79	78	85	80,6
5	1	0	38,4	37,7	38,1	38,07	89	90	85	88,0
6	-1	0	32,9	34,4	31,8	33,03	96	91	90	92,3
7	0	1	38,7	39,1	38,4	38,73	86	89	88	87,6
8	0	-1	35,1	34,5	34,8	34,80	78	76	80	78,0
Control						25				78

Dispersion analysis confirmed homogeneity of the sample variances. To determine quantitative dependence of the temperature of heating of pine seeds and their germination from the selected factors X₁ and X₂, a correlation and regression analysis was performed and adequate (with an experimental error of 5%) regression equations (4 and 5) were obtained:

$$y_1 = 36,3 + 3,29 \cdot x_1 + 2,71 \cdot x_2 - 0,95 \cdot x_1^2 + 0,67 \cdot x_1 \cdot x_2 \quad (4)$$

$$y_2 = 84,5 - 2,0 \cdot x_1 + 3,0 \cdot x_2 + 5,1 \cdot x_1^2 - 2,2 \cdot x_2^2 - 6,1 \cdot x_1 \cdot x_2 \quad (5)$$

Response surfaces were built using spreadsheet, table 2 (figure 1a, b).

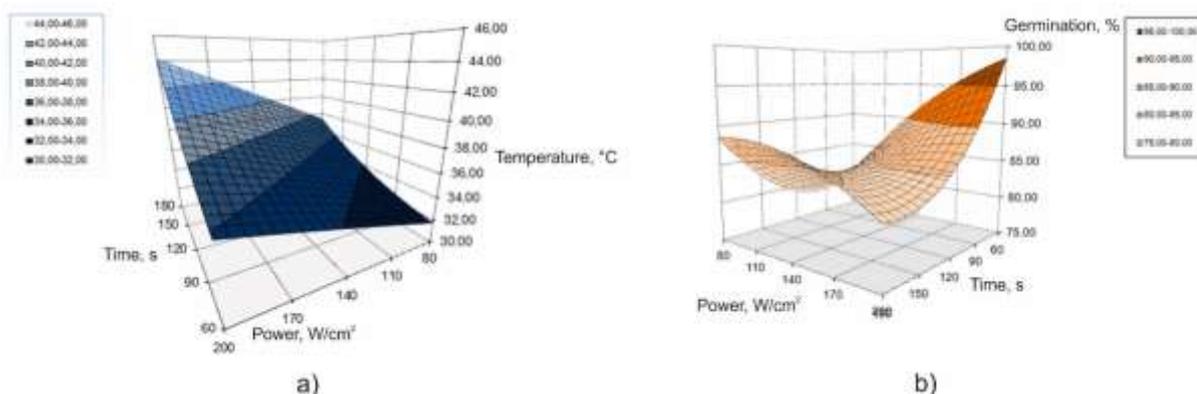


Figure 2 (a, b). (a) Dependence heating temperature on specific power and time of heating of the seeds in UHF EMF; (b) Dependence of germinating ability of pine seeds on specific power and time of treatment in UHF EMF.

Figure 2 (b) shows that maximum germinating ability of pine seeds of 97% corresponds to a minimum time of treatment of 60 seconds and maximum power density of 200 W/cm³. In this mode, the seeds were heated to 34°C. The mode with maximum values of specific power and time of treatment ($P_{\text{specific}} = 200 \text{ W/cm}^3$; $t = 180 \text{ s}$) heated the seeds to temperature of 42°C, while seed germinating ability made 81%.

Implementation of the plan matrix enabled obtaining adequate regression equations for laboratory-scale germinating ability of the seeds. Comparing equations and graphs of temperature and germination, we note that germinating ability is directly dependent on temperature.

Modes that create temperatures above 40 degrees Celsius are harsh and temperature itself is detrimental to the seeds. However, one cannot expect any effect of stimulation or depression, focusing solely on the heating temperature.

Comparing the results of laboratory-scale germinating ability of eight experiments of Kono-2 plan of seed treatment with UHF EMF energy, we can conclude that seed germinating ability in seven experiments increased by 2.6...19.3% compared to control, and one option remained at the control level, what confirms stimulating effect of UHF EMF.

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