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Experimental studies to identify ultraviolet radiation impact on tomato seeds ‘Rozoviy Novichok” seeding quality

To cite this article: N E Ponomareva *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **659** 012035

Experimental studies to identify ultraviolet radiation impact on tomato seeds ‘Rozoviy Novichok” seeding quality

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Abstract. Nowadays, organic farming is one of the innovative directions for the development of agricultural production. Its implementation is based on the principles of not using chemically synthesized fertilizers and plant protection products, but applying natural organic substances and creating conditions identical to the ones for natural plants growth. The most popular in this case are physical effects based on the conversion of electrical energy including conversion into light energy. It is well known that the use of optical radiation of the required intensity and duration makes it possible to stimulate intracellular processes in the seed and the plant itself. Such influencing factors primarily include ultraviolet radiation. Experimental studies to research the effect of pre-sowing treatment of tomato seeds “Rozoviy novichok” with radiation with a wavelength of 302, 313, 334 and 365 nm, exposure dose of 48; 72; 96 and 120 W s/m^2 and a treatment time of 60 seconds revealed a positive effect. The highest germination of seeds, lengths of shoots and seed roots as well as the diameter of the stem and the dry weight of stems, leaves and roots were obtained at the indicated values of the wavelength and radiation dose. It should also be noted that at these values of the wavelength and radiation dose, the height of the seedlings is minimal, which means that the seedlings will be more stocky, and their survival rate will be maximum. This approach enables to formulate requirements for the design and development of a specialized electrotechnical installation for pre-sowing stimulation of such vegetable crops as tomatoes.

1. Introduction

Today, it is impossible to intensify technological processes and increase the volume of harvested products in the crop sector of agriculture only by expanding the sown areas. It is stipulated by the fact that their territories are limited. It is also difficult to obtain high yields only due to regulation of mineral nutrition. Therefore, using modern advances in science and best practices aimed to increase yields and improve the quality of crops grown enables to achieve a significant increase in the economic efficiency of agricultural production.

The main task of agricultural production is to increase the yield of cultivated crops and obtain environmentally friendly products. This problem can be solved by developing and implementing effects of various physical factors on agricultural crops and, ultimately, on increasing the yield of grown crops. These factors primarily include the effects of electrical nature stimulating the growth and development of plants [1, 2, 3, 4, 5].

Ultraviolet (UV) radiation is part of the sun’s optical spectrum. The ultraviolet radiation itself can be used to irradiate seeds and plants and, as a consequence, to increase the yield and quality of products [6, 7]. This direction has not become widespread yet. However, it can be effectively used in solving the existing problems of producing crop on protected ground. With such a direct effect on plants, radiation can serve as an effective regulator of the main processes in a biological object. There are positive results on the development of methods for pest control of agricultural plants and disinfection of products during storage and processing [8].

The effect of ultraviolet radiation on seeds is based on the ability to cause photochemical transformations in the irradiated material, and these transformations are characterized by an improvement in metabolism (nitrogen, mineral, carbohydrate) due to the activity of enzymatic processes, especially redox ones [9, 10]. In the spectral range 200-300 nm, ultraviolet radiation is strongly absorbed by nitrogenous bases of nucleic acids, whose most important reactions are chemical oxidation, photochemical hydrogenation and photodimerization.

Ultraviolet irradiation is effectively used for pre-sowing treatment of seeds of various agricultural crops, from cereals to vegetables. The advisability of treating seeds with ultraviolet rays has been proven by numerous studies [11, 12, 13, 14, 15].

The effectiveness of applying ultraviolet radiation for pre-sowing stimulation of seeds is stipulated by the fact that in the region close to 350 nm the reflectivity of the seeds surface of most agricultural crops is minimal and does not exceed 15% [16, 17].

Despite numerous studies related to pre-sowing treatment of seeds with ultraviolet radiation, the issue of determining the rational range of radiation doses for various vegetable crops including tomatoes is still rather relevant.

The aim of the study is to determine the rational range of parameters (wavelength) and operating modes (radiation dose) of electrotechnical installations for seeds pre-sowing treatment with ultraviolet radiation.

2. Methods and Equipment

To obtain dependencies reflecting the relationship between the quality indicators of tomato seeds (germination, length of shoots and roots) and the wavelength and dose of radiation, an experimental plan was drawn up. When drawing up the plan of the experiment, the design features of the laboratory facility were taken into account. The experiment was carried out on the “LOS-2” installation with a DKsTV 6000 lamp being a radiation source. This radiation source has a significant advantage. Specifically, the radiation of xenon lamps is close to the natural solar spectrum, including the entire zone of the ultraviolet spectrum in the radiation spectrum of these lamps. In combination with replaceable filters included in the setup kit it enabled to isolate radiation with wavelengths of 302, 313, 334, and 365 nm.

The seeds of the variety “Rozoviy Novichok” were treated with radiation at the following dose values: 48; 72; 96 and 120 W s/m^2. The duration of the treatment was constant and equal to 60 s.

The irradiation level was varied by changing the lamp current and the degree of diaphragm opening. The amount of irradiation was monitored using a ufi-meter.

The number of seeds in the sample was 100. After establishing the required level of irradiation, the seeds were treated. The experiment and processing of the results were carried out in accordance with the methodology set in State standard 12038-84. In accordance with the State standard, seed germination was carried out between sheets of paper.

For this, the seeds were laid out in the germinating chambers between the layers of damp paper. For each treatment case, four samples were placed. The seeds were germinated under the conditions noted in State standard 12038-84, that is, at a variable temperature of 20-30°C. To determine the germination energy, germinated seeds were evaluated and accounted on the fifth day, and the germination capacity and length of shoots were determined on the tenth day.

Seed germination was calculated on a percentage base. The arithmetic mean of the germination of all analyzed samples was taken as the results of the analysis if the spread of the results of individual samples analysis from the arithmetic mean did not exceed the value specified in State standard 12038-84 when determining the seeds germination. When analyzing the spread of the germination of seeds of one of the four samples from the arithmetic mean by a value greater than the permissible spread, germination, germination energy and sprouts length were calculated based on the results of the analysis of the other three samples, and if the spread was higher than the allowable results of analysis of two samples, analysis repeated.

3. Results and Discussion

The results of the studies [18] according to the methods described above are presented in tables 1-2.

Table 1. Results of studying UV radiation effect on length of sprouts and roots of tomatoes "Rozoviy Novichok"

Radiation dose, W s/m^2	Length of shoots/roots, mm at wavelength			
	302 nm	313 nm	334 nm	365 nm
48	42.6/48.9	44.4/51.1	50.36/50.44	50.7/54.4
72	42.3/52.9	45.4/53.5	54.9/53.3	57.7/57.3
96	44.6/52.7	49.5/54.6	47.8/60.2	57.9/58.9
120	42.6/50.5	39.6/55.1	45.8/57.3	46.9/58.0

Table 2. Results of studying UV radiation effect on laboratory germination of tomato seeds "Rozoviy Noichok"

Radiation dose, W s/m^2	Germination,% at wavelength:			
	302 nm	313 nm	334 nm	365 nm
48	76.75	77.50	78.25	78.75
72	78.50	80.25	78.75	79.50
96	79.25	81.25	81.50	79.50
120	79.00	80.75	78.25	79.00

Laboratory studies, during which the effect of ultraviolet radiation with wavelengths and at values of radiation doses above on germination, seedling height, number of leaves, stem diameter, and dry weight of stems, leaves and roots were carried out with the objective to identify the influence of the parameters and modes of pre-sowing treatment of seeds with ultraviolet radiation on the indicators characterizing the productivity of the plant at different stages of its development, in particular at the seedling stage.

Germination was carried out under laboratory conditions in 0.3 liter beakers filled with soil. On the seventh day, according to State standard 12038-84, the germination of tomato seeds was determined.

After the emergence of seedlings, throughout the experiment, the illumination was maintained at 5.5 klx. For this, low-pressure fluorescent lamps LismaFL 80W - 32/635 with a power of 80 W were used. The temperature and humidity regime was maintained within the framework of agrotechnological requirements for this type of crop (temperature 18-20°C, humidity 65-70%) On the twenty-first day, according to State standard 12038-84, indicators characterizing plants at the seedling stage were measured. To determine the dry weight of stems, leaves and roots, plants were placed in drying ovens. Then the dry mass was measured. The research results are shown in tables 3-6.

Table 3. Results of studying UV radiation effect on seedlings height of tomatoes "Rozoviy Novichok"

Radiation dose, W s/m^2	Plant height, cm at wavelength:			
	302 nm	313 nm	334 nm	365 nm
48	18.28	17.82	18.82	16.17
72	18.83	16.66	16.47	16.38
96	14.40	15.87	16.36	18.45
120	16.45	19.70	17.86	19.04

Table 4. Results of studying UV radiation effect on number of leaves of tomato seedlings "Rozoviy Noichok" [12]

Radiation dose, W s/m^2	Number of leaves, pcs at wavelength:			
	302 nm	313 nm	334 nm	365 nm
48	22.42	21.79	19.61	18.47
72	22.22	19.22	17.47	18.16
96	20.38	20.80	18.38	19.29
120	20.08	21.20	19.02	19.44

Table 5. Results of studying UV radiation effect on stem diameter of tomato seedlings "Rozoviy Novichok"

Radiation dose, W s/m^2	Stem diameter, mm at wavelength:			
	302 nm	313 nm	334 nm	365 nm
48	2.71	3.01	2.82	2.79
72	2.96	2.94	2.59	2.77
96	3.02	2.96	2.91	3.06
120	2.78	3.30	3.08	2.92

Table 6. Results of studying UV radiation effect on dry weight of stems and leaves, and on dry weight of roots of tomato seedlings "Rozoviy Novichok"

Radiation dose, W s/m^2	Weight of stems and leaves/roots of seedlings, g at wavelength:			
	302 nm	313 nm	334 nm	365 nm
48	1.98/1.25	3.24/3.33	2.20/1.91	2.50/1.12
72	2.26/3.65	2.26/2.88	2.13/1.47	3.48/1.14
96	2.50/3.72	2.84/2.19	2.24/1.43	2.41/1.45
120	2.28/1.44	2.51/0.72	3.18/0.97	2.62/1.83

According to experiment outcomes, regression equations (1-8) were obtained and yield surfaces (Figures 1-8) were constructed using the program *Statistica*.

The regression equation showing the dependence of the sprout length L_{sprout} on the wavelength x and the radiation dose y, obtained from the experimental results, can be presented as follows:

$$L_{sprout} = -29.2818 + 0.1672 \cdot x + 0.6354 \cdot y - 0.0040 \cdot y^2 \ , \quad (1)$$

where $L_{germ.}$ is seedlings length, mm; x is wavelength, nm; y is radiation dose, W·s/m^2.

The regression equation showing the dependence of the root length L_{root} on wavelength x and radiation dose y, obtained from the results of experiments, can be written as follows:

$$L_{root} = 630.0322 - 3.5065 \cdot x - 0.1962 \cdot y + 0.0053 \cdot x^2 + 0.0030 \cdot y^2 \ , \quad (2)$$

where L_{root} is roots length, mm; x is wavelength, nm; y is radiation dose, W·s/m^2.

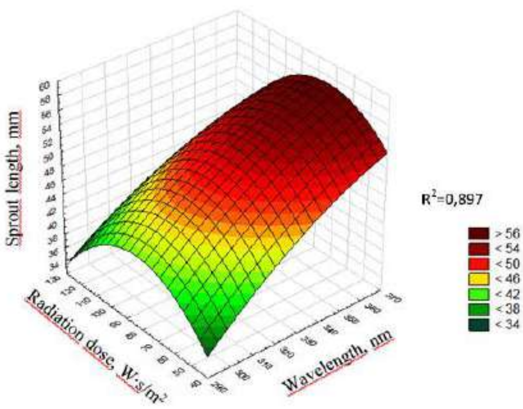

Figure 1. Dependence of tomato seedling length on radiation dose and wavelength

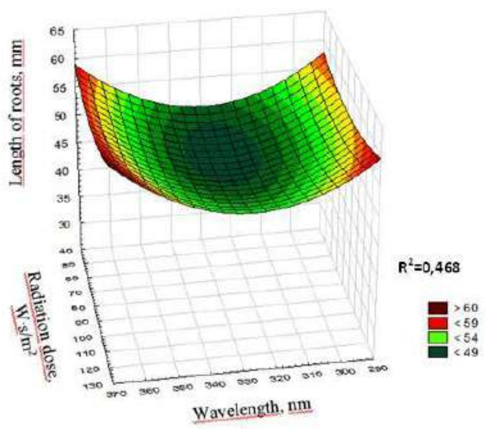

Figure 2. Dependence of tomato root length on radiation dose and wavelength

The regression equation showing the dependence of laboratory germination of tomato seeds Ws_{lab} on wavelength x and radiation dose y obtained from the results of experiments can be written as follows:

$$Ws_{lab} = 70.22187 + 0.20951 \cdot y - 0.00111 \cdot y^2 \ , \tag{3}$$

where Ws_{lab} is laboratory germination, %; y is radiation dose, W·s/m^2.

The regression equation showing the dependence of the seedling height H on the wavelength x and the radiation dose y obtained from the experimental results can be written as follows:

$$H = -0.3001 + 0.1436 \cdot x - 0.1927 \cdot y - 0.0002 \cdot x^2 + 0.0011 \cdot y^2 \tag{4}$$

where H is seedling height, sm; x is wavelength, nm; y is radiation dose, W·s/m^2.

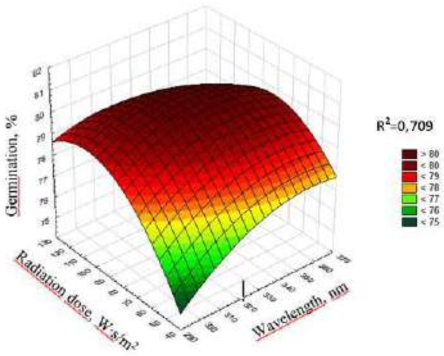

Figure 3. Dependence of the germination of tomato seeds on radiation dose and wavelength

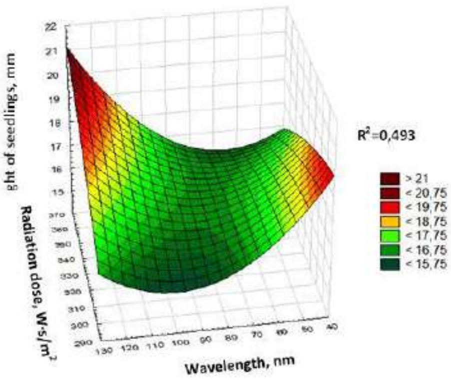

Figure 4. Dependence of seedling height on wavelength and radiation dose

The regression equation showing the dependence of the length of the shoots of the number of leaves N_{leaf} on the wavelength x and the radiation dose y obtained from the results of experiments can be written as follows:

$$N_{leaf.} = 1.0964 + 0.0111 \cdot x - 0.0006 \cdot y - 0.00001 \cdot x^2 + 0.00002 \cdot y^2 \ , \tag{5}$$

where N_{leaf} is number of leaves, pcs.; x is wavelength, nm; y is radiation dose, W·s/m^2.

The regression equation showing the dependence of the stem diameter D on the wavelength x and the irradiation dose y obtained from the experimental results can be written as follows:

$$D = 178.8065 - 0.8875 \cdot x - 0.1175 \cdot y + 0.0013 \cdot x^2 + 0.0007 \cdot y^2 \ , \tag{6}$$

where D is stem diameter, mm; x is wavelength, nm; y is radiation dose, W·s/m^2.

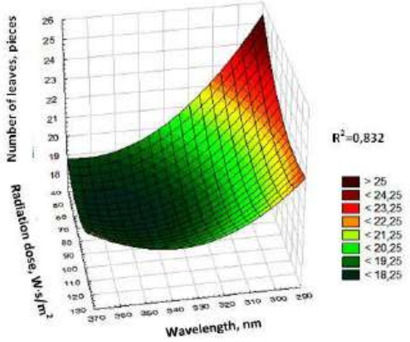

Figure 5. Dependence of quantity tomato seedling leaves on radiation dose and wavelength

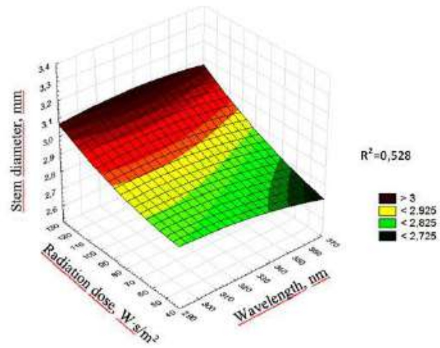

Figure 6. Dependence of stem diameter on wavelength and radiation dose

The regression equation showing the dependence of the dry mass of stems and leaves of seedlings M_{st} on wavelength x and radiation dose y, obtained from the results of experiments, can be written as follows:

$$M_{st} = -1.6076 + 0.0205 \cdot x - 0.0052 \cdot y - 0.00002 \cdot x^2 + 0.00001 \cdot y^2 , \quad (7)$$

where M_{cm} is dry mass of stems and leaves of seedlings, g.; x is wavelength, nm; y is radiation dose, W·s/m^2.

The regression equation showing the dependence of dry mass of seedling roots M_{root} on wavelength x and radiation dose y obtained from the results of experiments can be written as follows:

$$M_{root} = 54.4243 - 0.3154 \cdot x + 0.0891 \cdot y - 0.0004 \cdot x^2 - 0.0006 \cdot y^2 , \quad (8)$$

where M_{root} is dry mass of seedling roots, g.; x is wavelength, nm; y is radiation dose, W·s/m^2.

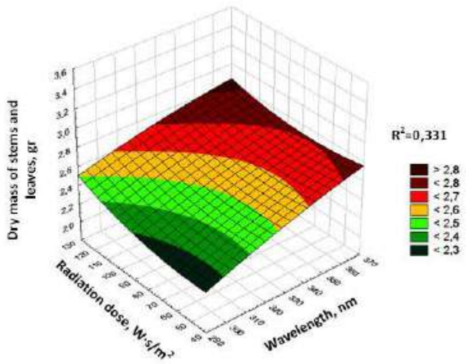

Figure 7. Dependence of dry mass of stems and seedling leaves on wavelength and radiation dose

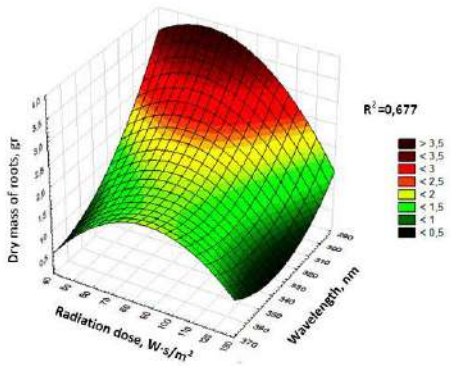

Figure 8. Dependence of dry mass of seedling roots on wavelength and radiation dose

The analysis of the obtained dependences enables to indicate a strong influence on the laboratory germination, the length of sprouts and the number of leaves of seedlings, the wavelength and radiation dose. For other indicators, the values of the coefficients fall within the range reflecting the average relationship between the productive qualities of plants and the parameters of ultraviolet radiation.

4. Conclusion

Thus, in the course of the search experiment, it was found that the highest stimulation efficiency according to the studied parameters is manifested at the values of the radiation dose and wavelength in the ranges of 80-105 W s/m^2 and λ=315-355 nm, respectively. At the indicated values of the wavelength and radiation dose, the highest germination of seeds, lengths of sprouts and seed roots, as well as the diameter of the stem and the dry weight of stems, leaves and roots were obtained. It should also be noted that at these values of the wavelength and radiation dose, the height of the seedlings is minimal, which means that the seedlings will be more stocky, and their survival rate will be maximum.

Acknowledgement

The authors would like to thank their colleagues for their contribution and support to the research. They are also thankful to all the reviewers who gave their valuable inputs to the manuscript and helped in completing the paper.

Conflict of Interest

The authors have no conflict of interest to declare.

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