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Effect of Laser Irradiation of Seeds on Growth Parameters Of *Dracocephalum moldavica* L.

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***Abstract*:**
The work analyzes the effect of laser irradiation on the similarity and growth indicators of the serpentine. The effect of laser irradiation of seeds with red and blue light on the growth parameters of Dracocephalum moldavica L. has been determined. The experiments used LED lasers characterized by coherent monochromatic radiation of red (635 nM) and blue (405 nM) light with a radiation capacity of 100 mW. As a result of the research, it was found that laser irradiation of seeds increased germination depending on the regime by 18.1-36.4 % compared to non-irradiated seeds. In 1.7-3.4 rad increased the number of plants that survived in experimental variants compared to control.
Plants grown from irradiated seeds were characterized by accelerated by 51.08-88.29% growth of root sittings and increased content of chlorophyll a and chlorophyll b. Irradiation of seeds by a blue laser with an energy of 25.05 mJ/cm^2 and coьplex irradiation by red rays with energy of 51.10 mJ/cm^2 and blue rays with energy of 25.05 mJ/cm^2 caused an increase in chlorophyll a by 135.7-1328.5 % and chlorophyll b by 84.7-14.8 % compared to control. This may indicate a significant activation of light receptor systems of the studied species.
***Keywords**: laser irradiation, D. moldavica L, growth rates, chlorophyll content*

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I. Introduction

Medicinal plants are used in medical practice as immunomodulating, anti-inflammatory, sedative and antiviral agents. In order to increase plant productivity, chemistry of agriculture is used worldwide. Excessive use of mineral fertilizers leads to changes in soil structure and causes environmental pollution and deterioration of product quality due to the accumulation of nitrates and nitrites. Therefore, there was a need to increase yields by other methods. Various stimulants of growth and development of plants of both chemical and physical nature began to be investigated. The physical factors of influence on plants, or rather on their seeds, tubers, bulbs, sprouts or adult plants at different stages of development [1, 2]. In such a situation, the search for environmentally friendly, promising methods of increasing yields becomes relevant. One such method is laser radiation.

It was experimentally found that laser radiation acts on both biological cellular structures and on a separate cell [3]. According to recent studies, the stimulation of seeds by laser radiation allows to increase the germination and growth energy within 20% and, as a result, to get a yield increase by 11−12% at low energy consumption [4]. It is known that plants need light for photosynthesis, but ultraviolet, red and blue light plays a significant role in the formation and regulation of growth. With the help of a photoreceptor called phytochrome, there is regulation of the life processes of plants under the influence of red light [5]. Plants are able to respond to the duration, quality and intensity of illumination using a phytochrome system, this process is called photomorphogenesis (change of forming and growth indicators) [6, 8]. The process of photomorphogenesis synchronizes plant growth, club formation, flowering and other processes associated with seasonal changes in the spectrum of sunlight. Phytochrome is able to capture changes in the ratio of far red (LC) and red (C) light. Phytochrome pigment plays an important role in optimizing the plant's structure, providing the most effective use of light in photosynthesis.

Laser irradiation is a continuous or pulse irradiation of seeds of agricultural and medicinal crops, and their shoots by laser beam of a certain wavelength, which ranges from 632 to 670 nm. The main purpose of this method is to increase grain yields, reduce morbidity, and develop a powerful root system of plants. Studies have shown that as a result of treatment of seeds with laser irradiation, plants develop faster and give more fruit [9, 10].

Scientists have found that plants with irradiation with a blue spectrum accumulate more biomass, and with red there is a high level of gas exchange. In addition to the accumulation of biomass, blue light causes differentiation of chloroplasts, opening of cotyledons and straightening of the apex of the shoot. Spectral properties of an additional pigment - pterin, allow kriptochrome to absorb quanta not only from the blue spectrum, but also from the near ultraviolet (UV-A). With the action of green and orange rays, the process of photosynthesis and the accumulation of dry matter in plants is minimal. In the accumulation of some primary substances and decomposition of carbon dioxide, only red rays are involved. Scientists have found that red rays provide high levels of gas exchange, photosynthetic activity, chlorophyll, carotene, anthocyanins, total carbohydrates and many other physiologically active substances [11, 12, 13]. Photoactivated plants develop faster, grow, are characterized by a larger assimilation surface, intense development of aboveground and root mass, which ultimately increases their yield, productivity and commodity. Thus, laser irradiation of seeds leads to a significant positive effect, since the seeds show an early stimulating effect, accelerate the development of plants, and increase their yield.

II. Material and Methods

The object of research was the growth reactions of the medicinal plant *Dracocephalum moldavica* L. (family Lamiaceae) for complex irradiation of seeds by coherent monochromatic light with a wavelength of 635 and 405 nm. Radiation of seeds with red rays (wavelength 635 n M) of the spectrum was carried out using a semiconductor laser BRP-3010-5 – 635nM, for irradiation with blue light used LED laser BRP-3010-5 – 405nM (manufacturer BOBLASER Co. China). Laser power was 100 mW. The effect of irradiation on similarity and growth indicators was studied. It was controlled by plants grown from non-irradiated seeds. Research was conducted using plans for a complete factor experiment with three levels of factors. Irradiation was carried out under the following irradiation regimes (Table. 1).Irradiation was carried out using a device that is designed for the complex action of LED laser systems on plant objects [14].

Table 1: Variants of seeds irradiation

Variant	Red Laser		Blue Laser	
	Irradiation period, sec.	Energy received, mJ/cm2	Irradiation period, sec.	Energy received, mJ/cm2
1	-	0	-	0
2	5	25.05	-	0
3	10	51.10	-	0
4	-	0	5	25.05
5	5	25.05	5	25.05
6	10	51.10	5	25.05
7	-	0	10	51.10
8	5	25.05	10	51.10
9	10	51.10	10	51.10

The research was conducted during 2020-2021. Sowing and care of plants were carried out in accordance with agrotechnical rules. All plants of control and research groups were grown in the same conditions of soil moisture, at temperatures of 20-24 °C and illumination of 10000 lx. Seed germination was determined on the 10th day after waxing on filter paper. Further cultivation of plants was carried out in conditions of soil culture. At the end of the experiment, plants measured the length of the main root and the height of the shoot. The content of chlorophyll was determined by spectrophotometric method in alcohol extract. Wintermans de Motsa formulas were used for computation of chlorophyl content[15].The obtained results were subjected to statistical processing by the method of dispersion analysis, the comparison of the average was carried out by the Dannet method [16, 17].

The works were carried out in the laboratory of the Department of Botany and Ecology of Vasyl Stus Donetsk National University.

III. Results and Discission

The results of the studies showed that the irradiation of seeds by monochromatic coherent light with a wavelength of 405 and 635 nm had a significant positive effect on the early stages of plant development, which depended on the spectral composition and radiation energy.

In particular, radiation with energy 25.05 and 51.10 mJ/cm^2 seeds D. moldavica red laser increased in 1.7-2.1 times the number of germinated seeds, but did not affect its germination. whereas exposure to blue laser with an energy of 25.05and 51.10 mJ/cm^2 was likely by 243.3% increased the number of germinated seeds compared to non-irradiated plants (Table 2) and 18.1% increased the germination of seeds in plants of this species. Irradiation of seeds with blue light with energy 51.10mJ/cm^2 had a less positive effect (var. 7). With these, the number of germinated seeds increased to 6.66 ± 1.08, compared to control (2.33 ± 1.08), and the germination of seeds increased by 22.8 %. The greatest positive effect was the complex cultivation of seeds with light rays of red and blue coherent monochromatic light (variants 5, 6, 8 and 9). Depending on irradiation energy and the ratio between blue and red irradiation energy, the germination of seeds *D. moldavica* increased by 18.1–27.3% compared to plants grown from non-irradiated seeds. The number of plants that survived under these conditions was also significantly greater than in control and ranged from 8.00 ± 0.70 to 9.33 ± 0.40 plants depending on the irradiation conditions of 10 planted plants. In the control version, this figure was 2.33 ± 1.08 plants out of 10.

Table 2. Effect of irradiation on seed germination *D. moldavica* L.

Vriant	Number of germinated seeds (out of 10)				Seeds germination, %			
	M ± m	D	D^D	% to control	M ± m	D	D^D	% to control
1	2.33 ± 1.08	-	-	100,0	7.33 ± 0.81	-	-	100,0
2	4.00 ± 0.70	1.66	2.92	171.7	6.66 ± 0.40	-0.66	1.90	90.9
3	5.00 ± 1.87	2.66	2.92	214.	9.00 ± 0.70	1.66	1.90	122.8
4	8.00 ± 0.00	1.66	2.92	343.3	8.66 ± 0.81	1.33	1.90	118.1
5	9.33 ± 0.40	7.00	2.92	400.4	10.00 ± 0,00	2.66	1.90	136.4
6	8.00 ± 0.70	5.66	2.92	343.3	9.33 ± 0.40	2.00	1.90	127.3
7	6.66 − 1.08	4.33	2.92	285.8	9.00 − 0.70	1.66	1.90	122.8
8	8.00 ± 0.70	5.66	2.92	343.3	8.66 ± 0.40	1.33	1.90	118.1
9	8.00 ± 1.22	5.66	2.92	343.3	9.33 ± 0.40	2.00	1.90	127.3

Note: in tables M – mean, m – error representativeness, D – difference between test and control averages, D^D – least significant difference according to the Dannet test

Thus, the irradiation of seeds by monochromatic coherent light using LED laser systems greatly accelerated the germination process and increased the number of living plants D. moldavica. Given the morphogenetic value of blue and red rays, it can be assumed that irradiation stimulates seed germination, increases its quality. Our research agrees with the results of other researchers [12, 14, 19]. Studies have shown a significant role of laser irradiation with red light of plant seeds in the formation and activation of growth processes, in particular germination of seeds. The above work also shows a significant role in accelerating the germination of blue coherent rays with a wavelength of 405 nm. The mechanisms of this stimulation are not yet fully understood, but at least five receptor systems of plants that perceive blue light (carotenoids, flavins, etc.) are known.

Combined laser irradiation had a likely positive effect on plant root growth (Table. 3). The length of the root, depending on the irradiation conditions, increased by 51.06-88.29 % compared to plants grown from non-irradiated seeds. The greatest effect on the growth of root systems was complex irradiation with red laser energies of 250 or 51.10 mJ/cm^2, and blue - 25.05 mJ/cm2 (variants 5 and 6). And with the energies of both lasers 25.05 mJ/cm^2 the length of plant roots increased by 81.38 % compared to control plants, and with the energy of the red laser 51.10 mJ/cm^2 and blue laser 25.05 mJ/cm^2 this parameter was 188.29 % compared to the length of the roots of plants grown from non-irradiated seeds. Irradiation of seeds with a complex of blue light with an energy of 51.10 mJ/cm^2 and red light with energies of 25.05 and 51.10 mJ/cm2 (variants 8 and 9) had a smaller effect on the length of the roots. In these processing options, the increase in root length was 52.65 and 68.61 % respectively. The treatment of seeds with red or blue laser with an energy of 25.05 mJ/cm^2 (variants 2 and 4) proved to be unlikely, although there was a tendency to increase this figure by 51.06 (variant 2) and 32.97 % (variant 4) compared to control plants.

Table 3. Effect of *D. moldavica* L.seeds irradiation on the growth parameters

Variant	Root length, cm				Stem height, cm			
	M ± m	D	D^D	% to control	M ± m	D	D^D	% to control
1	1.88 ± 0.26	-	-	100.0	3.50± 0.70	-	-	100,0
2	2.84 ± 0.34	0.95	1.08	151.06	3.05 ± 0.26	-0.44	0.93	87.14
3	3.01 ± 0.31	1.12	1.08	160.10	3.28 ± 0.27	-0.22	0.93	93.71
4	2.50 ± 0.20	0.61	1.08	132.97	3.43 ± 0.20	-0.06	0.93	98
5	3.41 ± 0.23	1.52	1.08	181.38	3.07 ± 0.13	-0.42	0.93	87.71
6	3.54 ± 0.21	1.65	1.08	188.29	3.63 ± 0.16	-0.13	0.93	103.71
7	3.04 ± 0.17	1.15	1.08	161.70	3.08 ± 0.15	-0.41	0.93	88
8	2.87 ± 0.24	0.98	1.08	152.65	3.13 ± 0.15	-0.36	0.93	89.42
9	3.17 ± 0.22	1.28	1.08	168.61	3.42 ± 0.21	-0.07	0.93	97.71

Results of determining the effect of laser irradiation of seeds *D. moldavica* showed no probable effect of the factor on this parameter of experimental plants. In all variants, a slight decrease in the height of the stem was observed under the conditions of seed treatment with both red (wavelength 63 nm) and blue (wavelength 405 nm) lasers on 2.29-12. 86 % compared to control plants (Table. 3). Only in the variant of complex treatment with coherent light with a wavelength of 635 nm and energy of 51.10 mJ/cm^2 and monochromatic coherent light with a wavelength of 405 nm and energy of 25.05 mJ/cm^2 (variant 6) there was a tendency to slightly increase the height of the stem. Under these conditions, the height of the stem was 103.71 % of the level of plants grown from non-irradiated seeds. These results disagree with the results obtained by other researchers [4,10, 14]. Perhaps this can be explained by the need for a more accurate selection of irradiation doses for this species of plant.

The study of the effect of LED seed irradiation by laser systems on the content of chlorophyll (Table. 4) made it possible to conclude a significant increase in the content of pigments in leavesof*D. moldavica* depending on seed irradiation regimes. Thus, the bridge of chlorophyll a increased in experimental plants by 1.2-2.3 times compared to control plants grown from non-irradiated seeds. The greatest effect was observed during irradiation by a blue laser with an energy of 25.05 mJ/cm^2 (variant7) and complex action of red (irradiation energy 25.05 mJ/cm^2_) and blue (irradiation energy 51.10 mJ/cm^2) lasers (variant6). Under these conditions, the content of chlorophyll a was 238.5 and 235.5 %, respectively, compared to control plants. The slightest effect was irradiation by monochromatic rays with a wavelength of 635 nm (red laser). The effect of red light on the seeds caused a seminal content of chlorophyll a at 23.1 and 52.9 % depending on the irradiation energy.

Table 4. Effect of *D. moldavica* L. seeds irradiation on the chlorophyl content

Variant	Content of chlorophyl *a*, mg/g				Content of chlorophyl *b*, mg/g				Ratio $\frac{Chl.a}{Chl.b}$
	M ± m	D	D^D	% to control	M ± m	D	D^D	% to control	
1	2.21± 0.02	-	-	100.0	1.44± 0.02	-	-	100.0	1.53
2	3.38± 0.02	1.17	0.72	152.9	2.38± 0.01	0.94	1.07	165.3	1.41
3	2.72 ± 0.33	0.51	0.72	123.1	1.57± 0.50	0.13	1.07	109.0	1.57
4	4.44 ± 0.45	2.23	0.72	200.9	2.26± 0.47	0.82	1.07	156.9	2.04
5	4.82 ± 0.09	2.61	0.72	218.1	2.66± 0.24	1.21	1.07	184.7	1.82
6	5.27 ± 0.13	3.06	0.72	238.5	3.28± 0.34	1.84	1.07	227.8	1.62
7	5.21 ± 0.17	3.00	0.72	235.7	3.24± 0.37	1.80	1.07	225.0	1.62
8	5.05 ± 0.40	2.84	0.72	228.5	3.08± 0.63	1.64	1.07	213.9	1.70
9	5.05 ± 0.09	2.84	0.72	228.5	2.22± 0.04	0.77	1.07	154.2	2.27

Changes in the content of chlorophyll b in response to the effect of irradiation of seeds had a similar character to chlorophyll, but were expressed to a lesser degree. In particular, red laser irradiation of seeds led to an increase in chlorophyll b content by 65.3 % for radiation energy of 25.05 mJ/cm^2 and 9.0 % for irradiation energy of 51.10 mJ/cm^2. With complex irradiation (variants 5, 6, 8, 9), the amount of chlorophyll in leaves increased by 27.8-113.9% compared to control plants depending on irradiation regimes. The greatest effect was achieved by irradiating the seeds with blue light with an energy of 25.05 mJ/cm2 and red light with 51.10mJ/cm2 energy. Under these conditions, the amount of chlorophyll b increased from 1.44±0.02 mg/g in control to 3.24±0.37 mg/g in the experimental variant. The greatest increase in the content of pigment in the leaves was determined by the exposure of seeds to blue light with an energy of 25.05 mJ/cm2 (variant 7. Under these conditions, the pigment content was 227.8% of the corresponding parameter of plants grown from non-irradiated seeds.

It should also be noted that studies have shown no significant changes in the ratio of chlorophyll a to chlorophyll b. It can be assumed that in all variants of irradiation, plants retain the relative constancy of photosystems, but their number increases, which should positively affect photosynthetic processes, and therefore the intensity of metabolism in general.

IV. Conclusion

Seed irradiation with LED laser systems with a laser capacity of 100 mW allowed to significantly increase seed germination and its survival in *D. moldavica*. That is, the seeds have increased viability, which may be the result of activation of the phytochrome system with red light with a wavelength of 635 nm and a system of flavin receptors activated by sons of light. Irradiated plants have a significant activation of growth processes of root systems and an increase in the synthesis of chlorophyll by exposure to seeds with a blue laser with a wavelength of 405 nm. Thus, the results obtained by us on the one hand confirm the conclusions given in other works [12, 14, 19]. On the other hand, the species specificity of the studied species was shown. In particular, more sensitivity to seed treatment with blue rays and less response to red rays has been shown compared to other plants.

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