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Determination of the activating effect of low-energy laser radiation on the root system of beans

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An experimental study to determine the activation effect of low-energy laser radiation on the physiological parameters of bean sprouts, affecting their root system. To conduct the experiment, a laboratory stand was built, which included: a control panel, a tank with nutrient solution and a holder for growing beans, sources of artificial lighting of plants and the design of their installation, aeration unit and laser installation. The tank with nutrient solution and holder was a hydroponic installation based on the method of hydrogen culture and floating platform system. The biostimulation solution itself contained a set of certain chemical elements and their concentrations for growing beans. The operation of the laboratory stand began with the supply of power to the control panel, and from it commands were given to turn on the sources of artificial lighting of plants, the aeration unit of the nutrient solution and the laser device. The technology of laser treatment of bean sprout roots was also developed, which was based on division of 30 sprouts into 3 groups of 10 units, the first and second groups were irradiated with a laser with appropriate parameters of wavelength and dose, and the third was control. The sprout was taken from the appropriate row and placed in a glass container over which was the emitter at a height of 0.01 m, while clearly affecting the suction zone of the root system, and then returned to its original position. According to the results of the experiment, a set of data was obtained that testifies to the effectiveness of laser stimulation of bean roots.

Keywords: *laser, hydroponics, irradiation dose, floating platform, stem height, diameter of stem, wavelength*

Problem statement and its urgency. Protected soil structures must provide the population with vegetable products in the off-season (winter-spring) period of the year. Growing vegetables in greenhouses is associated with significant energy, material and labor costs, therefore, to increase the efficiency of greenhouse vegetable growing requires study, generalization and application of new growing technologies, scientific and technical achievements to intensify physiological processes in biological objects, which prolongs the period receipt of products and improves its quality [1, 2].

Analysis of the results of recent research and publications related to the problem. The analysis of scientific and technical literature shows that to increase the productivity and quality of crops grown in protected soil structures, use the hydroponic method, which is based on growing plants without the use of soil. This method includes a number of methods and systems that have their advantages and disadvantages and differ in application depending on the type of culture. Recently, it is widely used both in our country and abroad. However, with the available advantages, it does not meet the needs of vegetable products in full. Scientists are developing technologies to increase plant yields in hydroponic plants based on the addition of mineral fertilizers of different concentrations to the nutrient solution, but they all lead to chemical contamination of fruits. Therefore, there is a need to find new environmentally friendly technologies to intensify plant development in hydroponics [3].

The purpose and statement of the problem. Experimentally determine the effect of laser radiation on the activation of physiological processes in beans variety "Saharnaja", which is grown hydroponically, with wavelengths and radiation doses $\lambda_1 = 405$ nm,

$W_1 = 0{,}1$ J and $\lambda_2 = 658$ nm, $W_2 = 0{,}4$ J. Achieving the goal is related to the following tasks: construction of a laboratory stand for the experiment, development of devices and irradiation system for the root system of beans.

The main material. To conduct an experimental study, a laboratory stand was created, consisting of: control panel 1; a tank with a nutrient solution and a holder for placing cultivated plants in it 2; sources of artificial lighting of plants and the design of their installation 3; the aeration unit of the nutrient solution 4; laser installation 5.

The control panel included: circuit breaker named iC60N with parameters B6A 2P, designed for connection to the network and protection against short circuit and overload currents; automatic switch series BA47-29 with technical parameters B 6A 1P, which performs the function of power supply to the control circuit and its protection against abnormal operating modes; signal lamp named LS47M (230 V, 0.5 W) in the amount of two units to signal the presence of power in the power circuit and control circuit; electromagnetic contactor of the KMI-11210 series (230 V, 12 A), intended for switching of a power supply circuit of lighting; push-button post for three places with two contacts of the N / O + N / C type and a signal lamp, which provides manual switching on and off of the electromagnetic contactor; electronic time relay named TM41 (240 V, 16 A), which is necessary for automatic switching on and off of artificial lighting of plants in certain periods of the day; multipole switch named PKP10 (230 V, 10 A), required for switching manual and automatic lighting control mode; two sockets (230 V, 16 A), for connection of the aeration unit and laser installation; input cable with plug for general power supply to the remote control, as well as wires for connecting electrical devices.

The tank with nutrient solution and a holder for placing plants in it, had the form of a container measuring 0,29x0,71x0,18 m and a volume of 40 liters, which was filled with biostimulation solution with a set of the following macronutrients: nitrogen (NH_2) 7,5 g/l , phosphorus (P_2O_5) 5 g/l, potassium (K_2O) 5 g/l, zinc (Zn) 0,24 g/l, copper (Cu) 0,22 g/l, molybdenum (Mo) 0,024 g/l, cobalt (Co) 0,012 g/l; trace elements: boron (B) 0,25 g/l, iron (Fe) 0,31 g/l, manganese (Mn) 0,25 g/l; vitamins: (B1) – 48, (C) – 134, (PP) – 115; humates: 11 g/l, succinic acid 96 mg/l; amino acids: methionine-40, glycine-40, lysine-134, tryptophan-48, necessary for the growth of beans, and expanded polystyrene plate size 0,3x0,73x0,015 m with holes with a diameter of 0,04 m in the amount of 30 units, in 3 rows 10 units each, with a gap between the holes of 0,06 m and a row spacing of 0,1 m, in which gauze was fixed and a bean sprout was installed. The first row was treated with a low-energy laser radiation with parameters $\lambda_1 = 405$ nm, $W_1 = 0{,}1$ J and $\lambda_2 = 658$ nm, $W_2 = 0{,}4$ J – was a control sample.

The installation for illumination consists of 4 fluorescent lamps like LB 20-1 with technical data of 20 W of 1060 lm; starting and regulating equipment: choke type 2UBI-20/220-VPP-110-UHL4 (20 W 220 V), in the amount of 2 units; starter name 4-22 W 220-240 V ~ Series with parameters 4-22 W 220-240 V, in the amount of 4 units; 2 compensating capacitors and a metal structure of their placement with the sizes of 0,5x0,99x0,5 m. The framework was established over the tank with the grown beans.

The aeration unit of the nutrient solution was composed of an oxygen compressor named Sonic 9908 with (220 / 240 V 6 W 480 l / h), necessary to provide oxygen to the root system of beans, which is in the nutrient solution of the hydroponic plant; a rubber branch pipe for oxygen transfer from the compressor to an air sprayer; a non-return valve that prevented the leakage of water from the tank through the compressor and the 0,6 m long mineral stone spray itself, which created a uniform oxygen saturation throughout the volume of the solution.

As a laser installation, the device "Lika-terapevt" was used, which was equipped with an electronic unit with the following technical parameters: the number of simultaneously operating channels 1; frequency of modulation of laser radiation 0,1-99,9 Hz $\pm$ 10 %; radiation time from 1 min to 99 min 59 s; recorded radiation dose 0,01-99,9 J $\pm$ 20 %, power consumption 15 W; power supply 220 V 50 Hz; remote handles type VRV1 with data: optical range – violet, wavelength 405 nm, maximum radiation power 50 mW; VRV5 with data: optical range - red, wavelength 658 nm, maximum radiation power 250 mW.

According to the classification of hydroponic plants [2], a tank with a nutrient solution and a holder for holding beans, we refer to the method of hydrogen culture and floating platform system. The study began with filling with a nutrient solution, with a certain set of chemical elements and their concentrations listed above, the tank. On the water surface of the tank was installed a holder with holes in which were placed the sprouts of beans germinated for 3 days on a cotton pad. Next, the general power supply was supplied to the control panel and the iC60N circuit breaker was switched on, which supplied voltage to the power circuit. Multi-pole switch PKP10, was installed in the position of automatic control of the plant lighting system and selected the necessary parameters of the electronic time relay TM41 to create the desired light regime of the crop. The BA47-29 circuit breaker, which supplied voltage to the control circuit, was switched on. The presence of voltage in this circuit made it possible for the time relay through its control contact to turn on the electromagnetic contactor KMI-11210 and thus create power to the plant lighting lamps, while providing 18 hours of daylight, and then unlock it over time. The accepted cyclicity was repeated for 7 days. Then, from the remote control, the aeration unit was turned on, which sent oxygen through a pipe to the spray available in the nutrient solution for oxygen enrichment of the root system of beans.

To irradiate the roots of beans grown in a hydroponic plant, the following technology was created: from the first row took a bean sprout and placed in a glass container over which was placed emitter at height $h = 0{,}01$ cm to create opportunities transfer of the planned dose, influencing a zone of absorption of a root, with parameters of the dose of electromagnetic energy $W_1 = 0{,}1$ J, which were installed on the electronic unit of the device and the wavelength of electromagnetic radiation $\lambda_1 = 405$, which was provided by the type of handle VRV1. After irradiation, the sprout returned to the installation, and so sequentially for each of the 10 units in a row. Then, in the same way, the second row was irradiated, but with different dose parameters $W_2 = 0{,}4$ and wavelengths $\lambda_2 = 658$ nm number of 10 units in a row. The third row performed the control function with the same number of sprouts. The total sample of the studied sprouts was 30 units. Irradiation occurred once a day, at dinner, starting from the first day of landing and lasted 7 days. The conditions of the process of laser treatment of the roots of bean sprouts are presented in fig. 1.

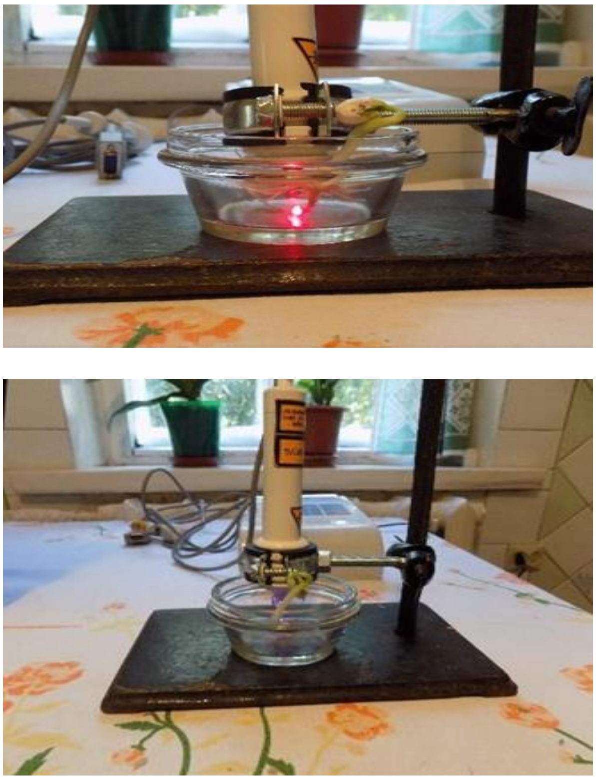

Fig. 1. Image of the process of laser treatment of the root system of beans "Saharnaja"

On each day of the experiment, the values of total salt content per unit volume were monitored, which should be equal to $ppm = 300$ and the degree of acidity or alkalinity, which should be $ph = 6{,}5$ of the nutrient solution. Activation of physiological processes in beans was recorded by the average height and average diameter of the stem. As a result of experimental research the data set on the basis of which the histogram of dependence of average height of a stalk was constructed was received $x_{aver.hei.}$ cm from the day of the experiment and the constant parameters of electromagnetic radiation for the first row of sprouts $\lambda_1 = 405$, $W_1 = 0{,}1$, for the second row of sprouts $\lambda_2 = 658$ and $W_2 = 0{,}4$, control fig. 2, as well as a histogram of the average diameter of the stem $x_{aver.diam.}$ cm from the day of the experiment and the constants given above, fig. 3. Excel 2013 information was used to build charts [3].

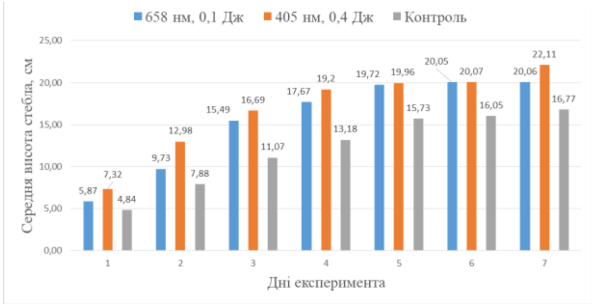

Fig. 2. Histogram of the dependence of the average stem height on the day of the experiment and the constant parameters of the electromagnetic radiation for each row of sprouts

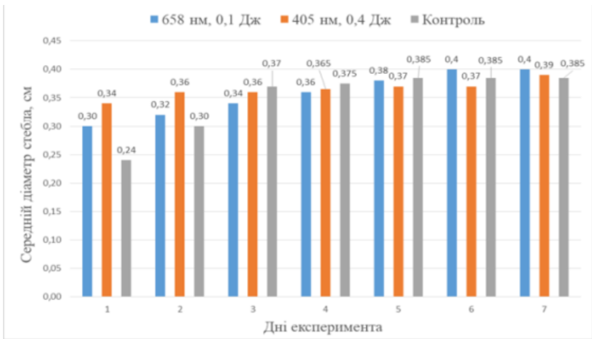

Fig. 3. Histogram of the dependence of the average diameter of the stem on the day of the experiment and the constant parameters of the electromagnetic radiation for a number of sprouts

Analyzing the above histogram, we can say that with increasing duration of the experiment is majestic $x_{aver.hei.}$ increases and at the end of the experiment is the largest of all groups of sprouts, however $x_{aver.hei.}$ sprouts, the roots of which were under the influence of laser radiation are larger than the control sample, and the largest value $x_{aver.hei.}$ achieved when $\lambda_1 = 405$ nm, $W_1 = 0{,}1$ J and falls. In addition, the largest jump in values was observed during the transition from the first to the second, and from the second to the third day of the experiment for each row. Considering this histogram, we can conclude that, as in the previous one, increasing the day of the experiment leads to a gradual increase $x_{aver.diam.}$ for all studied groups of bean sprouts, with the available constancy for 2, 3 days in the second row, 5, 6 days in the second and third rows, as well as 6, 7 days in the first row and control. Size $x_{aver.diam.}$ sprout where the root was treated with laser radiation is larger, compared with the control group, the largest $x_{aver.diam.}$ achieved on the 6th day of the experiment, when $\lambda_2 = 658$ nm, $W_2 = 0{,}4$ J.

Conclusions. Application of low-energy laser radiation with parameters$\lambda_1 = 405$nm, $W_1 = 0{,}1$ J for processing of root system of beans "Saharnaja" lead on day 7 before $x_{aver.hei.} = 20{,}1$ cm, which is 29 % more than the control and $x_{aver.diam.} = 0{,}4$ cm, 5 % more than control. Using parameters $\lambda_2 = 658$ nm, $W_2 = 0{,}4$ J lead on day 7 before $x_{aver.hei.} = 22{,}1$ cm, which is 32 % more than the control and $x_{aver.diam.} = 0{,}39$ cm, 3 % more than control. That is the obtained results show that the percentage of physiological indicators of bean activation at different parameters of electromagnetic radiation is different, with some parameters the average stem diameter is larger and the average stem height is smaller, and with others vice versa. Thus, it can be concluded that the use of low-energy laser radiation increases the values of individual beans, but requires further experiments and clarification of clear processing parameters for a combined effect on all growth rates of beans.

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Аннотация

Определение активирующего влияния низкоэнергического лазерного излучения на корневую систему фасоли

В. В. Сухин, Н. Л. Лисиченко, М. А. Чёрная

В данной статье представлено экспериментальное исследование по определению активационного влияния низкоэнергетического лазерного излучения на физиологические показатели ростков фасоли, влияя на их корневую систему. Для проведения опыта был построен лабораторный стенд, который включал в себя: пульт управления, резервуар с питательным раствором и держателем для размещения выращиваемой фасоли, источники искусственного освещения растений и конструкцию их установки, блок аэрации и лазерную установку. Резервуар с питательным раствором и держателем представлял собой гидропонную установку, основанную на методе водная культура и системе плавающая платформа. Сам биостимулирующий раствор, включал набор определенных химических элементов и их концентраций для выращивания фасоли. Функционирование лабораторного стенда начиналось с подачи питания к пульту управления, а с него подавались команды на включение источников искусственного освещения растений, блока аэрации питательного раствора и лазерного устройства. Также разработана технология лазерной обработки корней ростков фасоли, которая основывалась на разделении 30 ростков на 3 группы по 10 штук, первая и вторая группа облучалась лазером с соответствующими параметрами длины волны и дозы, а третья представляла собой контроль. Росток брался из соответствующего ряда и размещался в стеклянной емкости, над которой находился излучатель на высоте 0,01 м, при этом, четко воздействуя на зону всасывания корневой системы, а затем снова возвращался в исходное положение. По результатам опыта получено набор данных, свидетельствующие об эффективности лазерного стимулирования корней фасоли.

Ключевые слова: *лазер, гидропоника, доза облучения, плавающая платформа, высота стебля, диаметр стебля, длина волны.*

Анотація

Визначення активуючого впливу низькоенергетичного лазерного випромінювання на кореневу систему квасолі

В. В. Сухін, М. Л. Лисиченко, М. О. Чорна

Представлено експериментальне дослідження з визначення активізаційного впливу низькоенергетичного лазерного випромінювання на фізіологічні показники ростків квасолі, впливаючи на їх кореневу систему. Для проведення досліду був побудований лабораторний стенд, який включав в себе: пульт керування, резервуар з живильним розчином і тримачем для розміщення вирощуваної квасолі, джерела штучного освітлення рослин і конструкцію їх встановлення, блок аерації і лазерну установку. Резервуар з живильним розчином і тримачем представляв собою гідропонну установку основану на методі воднева культура і системі плаваюча платформа. Сам біостимуляційний розчин, вміщував набір певних хімічних елементів і їх концентрацій для вирощування квасолі. Функціонування лабораторного стенду починалося з подачі живлення до пульта керування, а з нього подавались команди на вмикання джерел штучного освітлення рослин, блока аерації живильного розчину та лазерного пристрою. Також розроблена технологія лазерної обробки коренів ростків квасолі, яка основувалась на розділенні 30 ростків на 3 групи по 10 одиниць, перша і друга група опромінювалась лазером з відповідними параметрами довжини хвилі і дози, а третя являла собою контроль. Росток брався з відповідного ряду і розміщувався в скляній ємності над якою знаходився випромінювач на висоті 0,01 м, при цьому, чітко впливаючи на зону всмоктування кореневої системи, а потім знову повертався у вихідне положення. За результатами досліду отримано набір даних, які свідчать про ефективність лазерного стимулювання коренів квасолі.

Ключові слова: *лазер, гідропоніка, доза опромінення, плаваюча платформа, висота стебла, діаметр стебла, довжина хвилі.*

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