Effect of pre-sowing seed treatment with semiconductor laser radiation on soft wheat productivity and its resistance to diseases

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Abstract. The study of the effectiveness of soft wheat seeds pre-sowing treatment with a continuous semiconductor laser (the wavelength of λ = 637 nm, the power density (Wp) of 2, 4, 8 W/m^2, the duration of exposure of 5, 30, 60 seconds) is presented in the work. The maximal increase in the wheat yield, as well as in the growth of most morphometric indicators of its productivity, was recorded in the experimental variant during pre-sowing seed treatment with the laser with a maximum power density of 8 W/m^2 and with the longest exposure time of 60 seconds. In addition, when seeds were irradiated with a laser with a maximum power density of 8 W/m^2, a decrease in the development of a complex of especially dangerous pathogens (helminthosporiosis root rot, septoria-pyrenophorous spotting, yellow rust) was observed. In general, with an increase in the power density of laser radiation and in the time of its exposure to seeds, the growth of the maximum number of morphometric indicators of wheat productivity and a decrease in the intensity of disease affect were revealed.

Keywords. Soft wheat, pre-sowing treatment, continuous semiconductor laser, productivity, diseases development.

1 Introduction

Wheat is one of the main crops in the Russian Federation. However, despite its importance, a wide distribution, and extensive experience in cultivation, crop yields are unstable and largely depend on a complex of agro-ecological factors [1]. Currently, the development of effective technologies for cultivation of grain crops based on the principles of resource conservation and implementation of the requirements of adaptive-landscape and precision farming is still ongoing [2]. At the same time, increasing grain crop yields is the most important problem of modern farming, which depends on the cultivar used by 50% [3], and is largely determined by soil and climatic conditions of the crop cultivation and phytosanitary condition of crops [4, 5]. A promising direction for increasing the sowing suitability of agricultural seeds is the use of electrophysical and electro-technological methods, including laser radiation, stimulating biological and physiological processes in them [6–9]. The development of research on determining the optimal parameters of laser impact on biological objects should provide a significant advancement of breakthrough technologies for solving urgent problems of modern agricultural production [10].

The aim of this work is to provide a biological rationale for the use of a continuous-wave semiconductor laser in the pre-germination treatment of soft wheat seeds.

2 Objects and methods of research

The plant material of the study was soft spring wheat known as *Triticum aestivum* L. (Leningradskaya 6, k-64900 cultivar) from the collection of wheat genetic resources of N.I. Vavilov All-Russian Institute of Plant Genetic Resources (VIR). Experimental studies were carried out at the VIR experimental field.

The experiment scheme included control (seeds without treatment), variants with pre-sowing treatment of seeds with a continuous semiconductor laser with a wavelength of 637 nm. The optical system was used to create a field of uniform illumination, the power density of which was set by filters. The scheme of the installation is shown in Fig. 1. The following exposure modes were selected: power density (Wp) of 2, 4 and 8 W/m^2 at exposure time (t) of 5, 30 and 60 sec. Seeds were irradiated in groups of 150 pieces; the time was controlled by a stopwatch.

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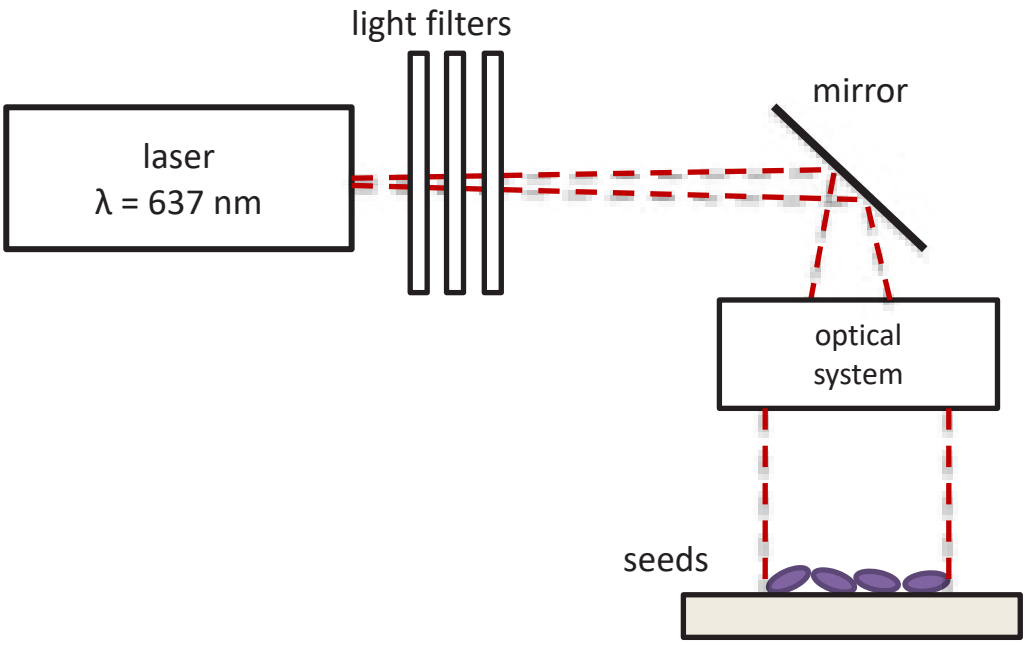

Fig. 1. The schematic diagram of the installation of pre-sowing seed treatment by laser radiation.

Under field conditions, wheat samples were sown on plots with an area of 1.0 m^2 by the row sowing method with the row spacing of 15 cm and the row spacing of 1 – 2 cm (300 grains/m^2). Experimental studies were carried out in triplicate. The phytometric characteristics of wheat crops were described using the indices. They are the field germination, the plant phase, the plant height, the number and length of primary roots, the number and the length of nodal roots, root weight, productive bushiness, total bushiness. There is also the flag leaf area, the pre-flag leaf area, vegetative part weight, the spike length, the number of spikelets per spike, spike weight, the grains number per spike, grain weight per one spike. These involve 1000 grains weight, the grains number per spikelet of a spike, grain weight per spikelet of a spike, the number of empty spikelets in a spike. In addition, the biological yield of wheat (g/plant) and, on its basis, the potential yield per unit area (t/ha) were calculated, taking into account the data on field germination, which determines the stem density of crops [11. The intensity of wheat affection by disease was described according to a set of conventional and calculated phytopathological indices. They are root rot and septoriosis-pyrenophorous spot (development (%)); yellow rust (development (%)), the number of strips with pustules (pcs.), the strip length with pustules (mm), the number of pustules in the strip (pcs.), the total number of pustules on the leaf (pcs.), pustule area (mm^2) [12].

3 Results and discussion

Significant increases in the biological Y_b (by 38.3% to 3.6 g/plant and by 58.0% to 4.1 g/plant) and potential yield Y_p of wheat (by 67.9% to 7.0 t/ha and 38.3% to 5.8 t/ha) compared to the control (Y_b=2.6 g/plant, Y $=_p$ 4.2 t/ha) was detected by pre-sowing seed treatment. It was conducted using continuous semiconductor laser with the power density of 8W/m^2 and the exposure time of 30 sec and 60 sec (Figs. 2 and 3).

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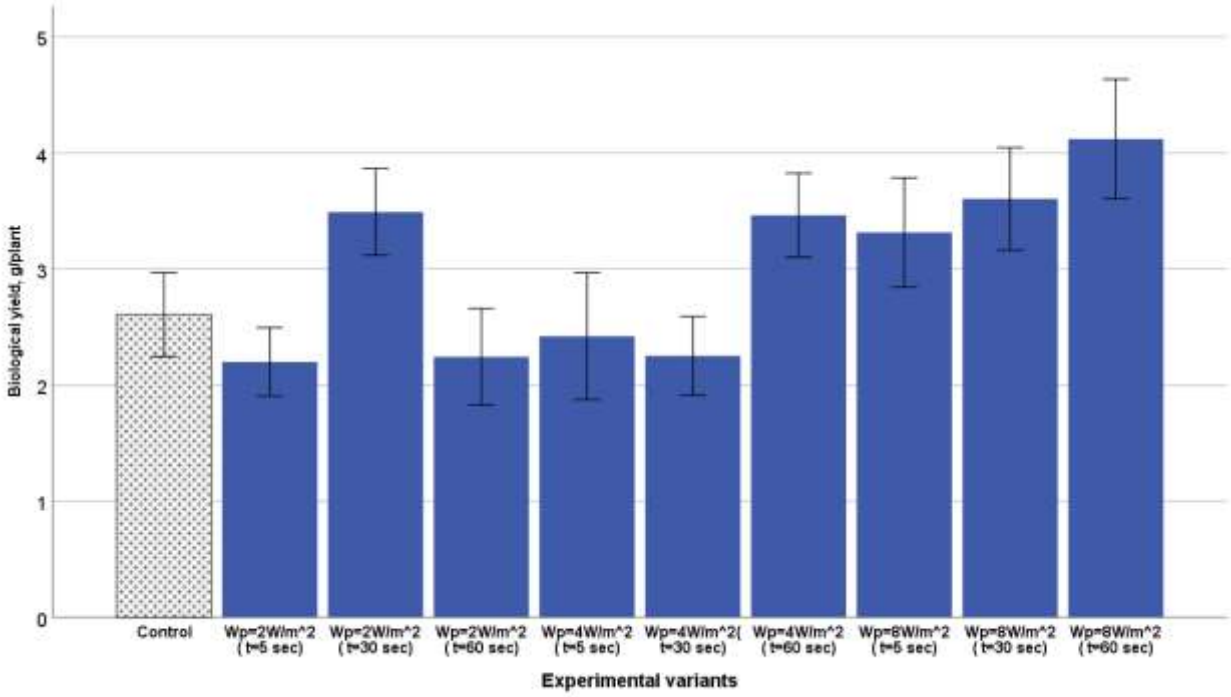

Fig. 2. The biological yield of the soft wheat cultivar "Leningradskaya 6, k-64900" during pre-sowing seed treatment with continuous semiconductor laser (in 2022)

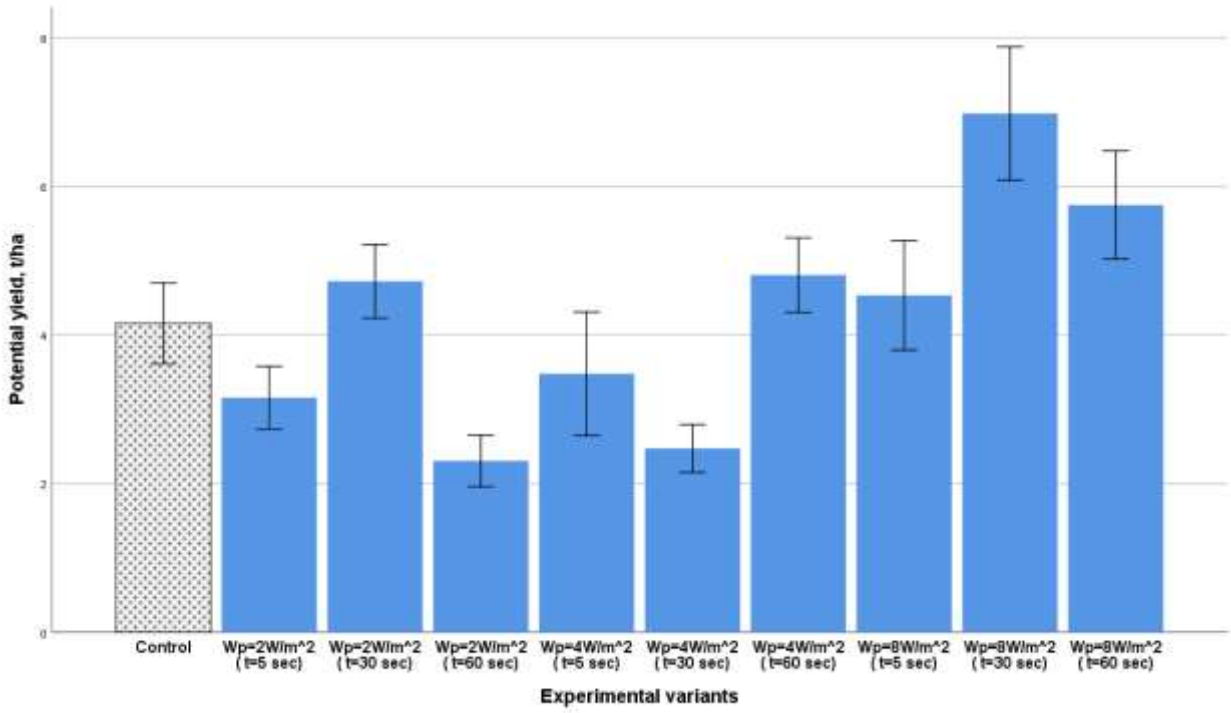

Fig. 3. The potential yield of the soft wheat cultivar "Leningradskaya 6, k-64900" during pre-sowing seed treatment with continuous semiconductor laser (in 2022).

Significant growth of Y_b and Y_p during pre-sowing treatment of wheat seeds with semiconductor laser in the experiment variants of "wp=8W/m^2, t=30 sec" was due to (at $P<0.05$) a reliable increase compared to the control. The root weight increased by 63.2% with an insignificant (at $P>0.05$) increase in field germination of seeds by 5.6%. The number of nodal roots increased by 20.1%, the length of nodal roots by 7.1%, productive bushiness by 22.3%, total bushiness by 25.1%, the weight of 1000 grains by 2.6%. The reduction of plant damage by root rot increased by 3.3%, septoriosis-pyrenophorous spot by 21.0% and yellow rust by 9.3%.

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In the experiment variant of "Ps=8W/m^2, t=60 sec", the reliable increase in plant height was by 8.5%, the number of primary roots increased by 109.6%, productive bushiness by 44.1%, total bushiness by 49.1%. The spikelets number per spike increased by 15.4%, the insignificant growth of the spikelet length was by 0.3%, the spikelet weight increased by 0.8%. This included the reduction of plant damage by yellow rust by 26.4% in the length of the strip with pustules, by 41.8% in the number of pustules in the strip, by 47.6% in the total number of pustules per leaf.

In all the variants of the experiment, when seeds were treated with laser before sowing, a significant lengthening of the interphase period of plant growth (by the phase of ontogenesis) was registered, except for the variant of "wp=8W/m^2, t=60 sec", where no significant change in the index compared to the control was observed. The maximum growth of the plant height (by 8.5%) was revealed in the experiment variant of "wp=8W/m^2, t=60 sec", as well as in the variants of "wp=4W/m^2, t=30 sec", "wp=4W/m^2, t=60 sec" by 7.3% and 5.9%, respectively.

The pre-sowing treatment of seeds by laser at wp=8W/m^2 with a maximum duration of exposure of t=60 sec caused the growth of the number of primary roots of wheat by 109.6%, while in the experiment variant of "wp=4Wp/m^2, t=30 sec" the decrease of this indicator by 36.7% was revealed. In the experiment variant of "wp=8Wp/m^2, t=60 sec", the maximum growth of the root weight by 15.4% was observed. Also, a significant increase in the root weight was found in the experiment variants of "wp=2W/m^2, t=60 sec" by 9.2% and "wp=8W/m^2, t=5 sec" by 9.1%.

The statistically significant decrease in the length of primary roots was revealed in the experiment variants of "wp=2Wp/m^2, t=60 sec" by 14.9% and "wp=4W/m^2, t=5 sec" by 16.8%. In the experiment variant of "wp=8W/m^2, t=60 sec", a significant decrease in the number and length of nodal roots was revealed (by 55.5% and 12.8%, respectively). At the same time, the maximum increase in productive and total bushiness (by 44.1% and 49.1%, respectively) was recorded in the above variant. The weight of the vegetative part of the plants significantly decreased in "wp=2W/m^2, t=5 sec" by 14.4%, in "wp=2W/m^2, t=30 sec" by 14.5%, in "wp=8W/m^2, t=5 sec" by 14.1%.

With regard to the elements of the wheat spike structure, the pre-sowing seed treatment with semiconductor laser had the following effect. The maximum increase in the spikelets number per spike was found in "wp=8W/m^2, t=60 sec" by 15.4%. In addition, a significant increase in the indicator was observed in "wp=2W/m^2, t=60 sec" by 9.2% and in "wp=8W/m^2, t=5 sec" by 9.1%. The significant decrease in the spike weight was revealed in "wp=2W/m^2, t=30 sec" by 48.2% and in "wp=2W/m^2, t=60 sec" by 44.2%. The "wp=4W/m^2, t=5 sec" variant decreased by 38.7%, the spikelet length of "wp=2W/m^2, t=5 sec" by 11.5%, "wp=2W/m^2, t=30 sec" by 8.7%, "wp=2W/m^2, t=60 sec" by 8.3%. And the grains number per spike of "wp=8W/m^2, t=60 sec" deceased by 14.5%. The weight of grains in the spike significantly decreased in "wp=2W/m^2, t=5 sec" by 19.4% and in "wp=2W/m^2, t=60 sec" by 28.7%, where a significant decrease in the weight of 1000 grains was also recorded (by 21.9%). In the experiment variant of "wp=8W/m^2, t=60 sec", the grains number per spikelet of spike decreased by 9.6%, but their weight did not change significantly. A significant decrease in the grains weight per spikelet of spike was observed in "wp=2W/m^2, t=60 sec" by 30.0% and "wp=4W/m^2, t=5 sec" by 18.7%.

The development of helminthosporiosis root rot in the control variant of the experiment in 2022 was insignificant (Fig. 4). No symptoms of disease development were observed in the experiment variant of "wp=8W/m^2, t=5 sec". The significant increase in the intensity of plant disease damage compared to the control was registered in the experiment variants of "wp=8W/m^2, t=5 sec" by 7.6% and "wp=4W/m^2, t=60 sec" by 6.9%.

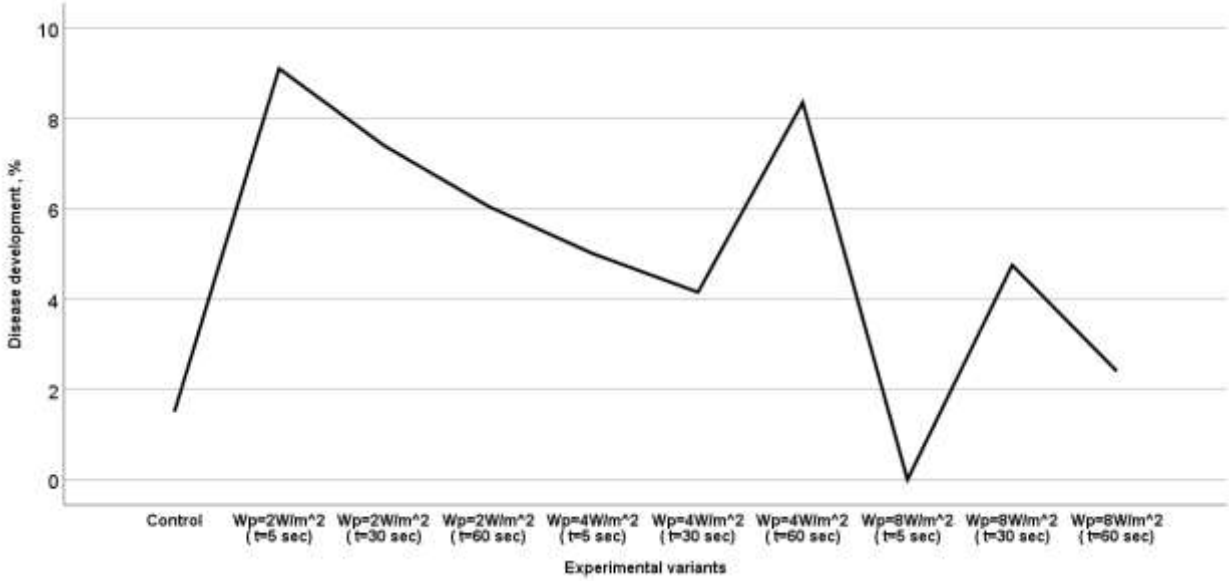

Fig. 4. Development of root rot on the cultivar "Leningradskaya 6, k-64900" during pre-sowing seed treatment with continuous semiconductor laser (in 2022).

Soft wheat leaves have not been affected by septoriosis-pyrenophorosis leaf spot in "wp=4W/m^2, t=60 sec", and in "wp=8W/m^2, t=5 sec" the disease development significantly decreased (by 29.8%). The biological efficiency (BE) of pre-sowing treatment of wheat seeds with laser was 70.4%. The tendency of disease development strengthening (by 20.2%) in "wp=8W/m^2, t=60 sec" was revealed.

The greatest reduction of plant damage caused by yellow rust pathogen was detected during pre-sowing treatment of wheat seeds with laser (wp=8W/m^2). However, the values of individual phytopathological indicators varied with the time of exposure. At t=5 sec, the disease development was 13.0% (Fig. 5), the number of strips with pustules on leaf was 56.2%; at t=60 sec, the length of strip with pustules was 26.4%; the number of pustules in the strip was 41.8%; the total number of pustules per leaf was 47.6%.

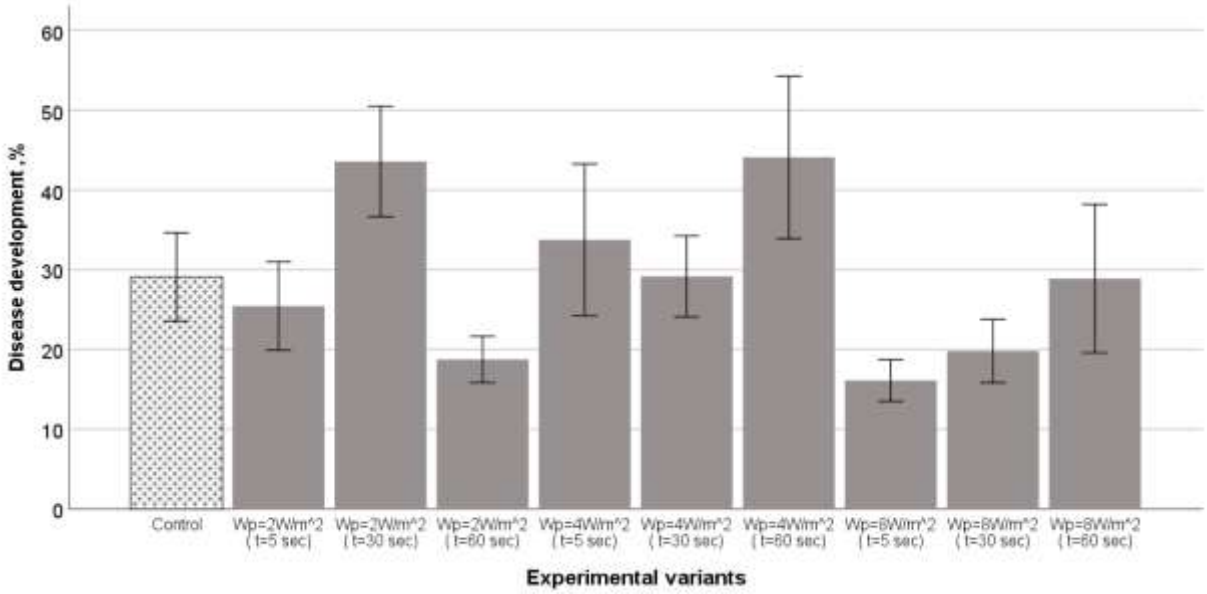

Fig. 5. The development of yellow rust on flag leaf of the soft wheat cultivar "Leningradskaya 6, k-64900" during pre-sowing seed treatment with continuous semiconductor laser (in 2022).

In general, the greatest number of morphometric indicators, the values of which increased and significantly increased (P<0.05) in comparison with the control during pre-sowing treatment of seeds with laser, was revealed in the experiment variant of "wp=8W/m^2, t=60 sec" (33.1 and 23.8%, respectively). Also, in the above-mentioned variant of the experiment, the greatest decrease in the values of the complex of phytopathological indices characterizing the intensity of wheat damage by a complex of diseases was revealed (71.4% (P>0.05) and 13.3% (P<0.05)).

It should be noted that recently a large number of scientific papers have appeared, which emphasise the positive effect of laser radiation on seeds, stimulating plant growth and development. Some works [13–15] provide data on a significant increase in plant productivity and reduction of disease damage. It is emphasised that the effectiveness of laser pre-sowing seed treatment is determined by the different responsiveness of crop species and cultivars to photobiological processes. In this regard, for each crop and cultivar it is necessary to select the optimal power density and multiplicity of irradiation of seeds with laser radiation. According to the results of our research, the greatest efficiency of pre-sowing treatment of wheat seeds of the "Leningradskaya 6" cultivar with laser radiation (λ=637 nm, wp=8 W/m^2) was revealed at the maximum duration of exposure of 60 sec.

4 Conclusions

The maximum growth of the wheat yield, as well as the number of morphometric indicators of productivity, the values of which increased and significantly increased (P<0.05) compared to the control during pre-sowing treatment of seeds with semiconductor continuous laser, was revealed in the experimental variant of "w=8W/m^2, t=60 sec". Also, in this variant the greatest reduction of the complex of phytopathological indicators characterizing the intensity of wheat damage by especially dangerous pathogens (helminthosporiosis root rot, septoriosis-pyrenophorous spotting, yellow rust) was observed. The tendency of phytometric values growth and phytopathological indices decrease in wheat crops with increasing power and time of laser radiation exposure on seeds used for seed pre-sowing preparation was revealed.

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