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Research Article

Combination Laser Irradiation Effect on Growth Parameters and Chlorophyll Content of Selected Poaceae Plants

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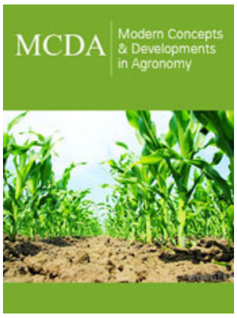

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Abstract

The effect of monochromatic coherent light with a wavelength of 635 and 405nm, which was generated by LED lasers with a power of 100mW, was studied to assess growth parameters of some species of Poaceae family plants (*Triticum aestivum* L., *Avena sativa* L., *Zea mays* L.), was. It was found that the germination readiness and germination ability of the investigated plants were likely to increase only with the combined action of red and blue light for 10 sec. Growth parameters of plants significantly increased (10.4-124, 5%) by depending on the dose and spectral composition of the irradiation. The most effective is red light and complex radiation for 10 seconds. The content of chlorophyll a and chlorophyll b is probably influenced by the complex (red and blue light) laser irradiation of seeds.

Keywords: Monochromatic coherent light; Poaceae plants; Growth parameters; Chlorophyll

Introduction

The use of chemicals aimed at improving plant performance (artificial growth additives, retardants, mineral fertilizers, etc.) can cause environmental pollution, deterioration of living organisms and a decrease in product quality [1-3]. Taking these conditions into consideration, an important problem of low-toxicity growth-promoting agents that can influence the processes of plant development without harming the ecological situation arises [4,5]. However, the most promising methods of regulating plant growth parameters, which are characterized by the slightest influence on the environment are the physical methods of impact on plants [1,6,7].

One of the most common physical methods of plant growth stimulation is using near infrared light emitted by He-Ne lasers for pre-sowing seed treatment [8,9]. It was found that a shortwave coherent red-light radiation with a wavelength of 620-660nm increased the emergence rate and seed germination [6, 7,10,11]. Plants grown from radiated seeds possessed the increased activity of growth promoters (i.e., indoleacetic acid, gibberellins, cytokinins); at the same time the activity of growth inhibitors decreased [11-13]. Morphological characteristics of such plants were improved [14], the activity of photosynthetic agents, enzymes in charge of the amino acid synthesis, lipid synthesis and carbohydrate synthesis were increased [13,15,16] as well as the intensity of photosynthesis [17]. Plants grown from laser-stimulated seeds used mineral nutrition elements better [18]. The positive effect of the red-light laser radiation was also observed when plants were exposed to elevated levels of ultraviolet radiation [6,19-21].

However, He-Ne laser machines require significant power supply and are characterized by lack of mobility. The radiation of He-Ne lasers is also limited in its spectral characteristics. It is possible to use LED laser systems to overcome these shortcomings, as they require less energy for providing the same radiation power and are characterized by small size and mass as well as high efficiency in affecting plant organisms [22-26]. In this regard, the effect of radiation with red (wavelength of 635nm) and blue (wavelength of 405nm) light produced by LED lasers on the growth parameters of selected species of the Poaceae plants was examined.

Materials and Methods

Physiological and biochemical reactions of plants on the combination laser radiation of seeds with coherent monochromatic light with a wavelength of 635 and 405nm was the object of this research which was carried out over such species of Poaceae plants as *Avena sativa* L., *Triticum aestivum* L., *Zea mays* L. The seeds were exposed to the laser radiation on bibulous paper in Petri dishes according to DSTU (State Standards of Ukraine) 41382002 ("Seeds of agricultural crops – quality assessment") in order to observe the effects on the germination readiness and germinating ability of seeds. The plants were grown in soil culture for 30 days at the temperature of 24 °C to observe the effects of combination radiation. The cultivation was carried out in plastic 0.5-liter containers, filled with sieved soil. Ten plants were planted in each container. Combination laser radiation was carried out according to a scheme of a complete two-factor experiment with three levels of factors (Table 1). The measurement of growth parameters was taken according to standard methods. The content of pigment was determined using a spectrophotometric method [25]. The obtained results were statistically analyzed using the dispersion analysis method. The means of samples were compared using the Dannet method [23,24].

Table 1: Variants of combination laser radiation of seeds.

Variant	Red Laser (635nm)		Blue Laser (405nm)	
	Irradiation term, sec	Irradiation energy, mJ/cm^2	Irradiation term, sec	Irradiation energy, mJ/cm^2
1	0	0	0	0
2	5	25.05	0	0
3	10	51.1	0	0
4	0	0	5	25.05
5	5	25.05	5	25.05
6	10	51.1	5	25.05
7	0	0	10	51.1
8	5	25.05	10	51.1
9	10	51.1	10	51.1

Results and Discussion

The results of the research showed that the combination laser radiation of seeds with red and blue light had a mixed effect on the germination readiness, germinating ability and growth parameters of the plants that were assessed in this experiment.

Thus, during the combination radiation of *Triticum aestivum* seeds in all experiment variants, except for the energy of irradiation 25.95mJ/cm^2 to the blue laser (var. 4), there was no probable effect on the seed germination readiness. During the 5-second exposure to the blue rays, the seed germination readiness of this species was lower than a similar index of control plants by 23.9%. A similar pattern was observed in changes of the germinating ability of the *T. aestivum* seeds. In the variant with the five-second radiation using a blue laser, this indicator comprised 89.8% from the level of the seeds which were not exposed to radiation (Table 2). Laser exposure also did not have a significant effect on the seeds' germinating ability in most of the used variants. Only in two modes of exposure there was a rise of this indicator compared with the control plants. Therefore, for combination radiation of the red (5 seconds) and blue rays (10 seconds) and combination radiation with both lasers for 10 seconds each (var. 8 and var. 9), this indicator was 100.8% and 101.4% respectively, compared with the control plants.

Table 2: Effect of combination laser radiation on germination readiness and germinating ability of seeds.

Variant	Germination Readiness			Germinating Ability		
	M±m	%	% To control	M±m	%	% To control
			Triticum aestivum			
1	49.0±0.6	98	100	49.3±0.6	98.6	100
2	47.3±0.6	94.6	96.5	49.3±0.6	98.6	100
3	47.3±2.1	94.6	96.5	47.7±1.5	95.4	96.7
4	37.3±1.2**	74.6	76.1	44.3±0.5**	88.6	89.8
5	45.7±0.6	91.4	93.2	48.3±2.1	96.6	97.9
6	47.7±0.6	95.4	97.3	49.0±1.0	98	99.4
7	47.7±1.1	95.4	97.3	49.0±1.0	98	99.4
8	48.3±0.6	96.6	98.6	49.7±0.6	99.4	100.8
9	49.3±1.1	98.6	100.6	50.0±0.0	100	101.4

			Avena sativa			
1	45.3±2.1	90.6	100	46.0±1.0	92	100
2	41.0±3.6	82	90.5	44.3±2.1	88.6	96.3
3	44.3±1.1	88.6	97.8	46.7±1.5	93.4	101.5
4	44.3±0.6	88.6	97.8	45.0±1.0	90	97.8
5	45.0±0.0	90	99.3	46.7±1.5	93.4	101.5
6	45.0±1.7	90	99.3	47.3±2.1	94.6	102.8
7	46.0±0.0	92	101.5	48.3±1.1	96.6	105
8	43.7±1.5	87.4	96.4	46.0±2.0	92	100
9	42.3±2.5	84.6	93.4	45.0±1.0	90	97.8
			Zea mays			
1	39.3±4.2	78.6	100	43.0±1.0	86	100
2	40.0±1.0	80	101.8	47.3±1.1	94.6	110
3	38.8±0.6	77.6	98.7	47.8±0.6	95.6	111.2
4	34.8±1.5	69.6	88.5	48.3±2.0	96.6	108.5
5	34.8±3.8	69.6	88.5	49.3±0.6	98.6	114.6
6	40.0±1.7	80	101.8	48.8±1.1	97.6	113.5
7	39.3±1.5	78.6	100	48.8±1.5	97.6	113.5
8	37.0±3.0	74	94.1	47.3±2.9	94.6	110
9	37.3±5.5	74.6	94.9	49.0±1.0	98	113.9

The combination laser radiation by coherent monochromatic light had a positive effect on *Avena sativa* seeds when assessing the germination readiness with blue laser radiation for 10 seconds (var. 7). Under these conditions, the germination readiness was likely to increase by 1.5%. Other modes of exposure did not have a similar effect on seed germination readiness. The germinating ability of the *A. sativa* seeds did not show a probable change in response to radiation with the red and blue lasers in any of the variants. The irradiation of the *Zea mays* for 5 seconds with red light (var. 2) and the combination radiation of the red laser for 10 seconds and the blue laser for 5 seconds (var. 6) increased the seed germination readiness by 1.8%. Other combinations of radiation did not influence or somewhat reduced this parameter. The germinating ability of the *Z. mays* seeds in all variants of radiation with red and blue lasers increased by 8.5-14.6% in comparison with control plants, which ranged from 94.6% to 98.6%, whereas among control plants this index was 86,0%. The most substantial increase in germinating ability of the seeds was observed with a combination of five-second radiation with the red light and five-second radiation with the blue laser. Under these conditions, the seed germination was 98.6%, which was 14.6% higher than the index of the control plants.

It seems that such insignificant influence of seed radiation on germination readiness and germinating ability can be explained with high natural germination readiness and germinating ability of seeds of these species, which ranges from 86.0% to 98.6%. At the same time, it should be noted that radiation of the seeds caused a faster emergence of seedlings. In particular, seeds exposed to the blue laser had their first roots to appear 1-2 days earlier than plants grown from control seeds. Radiation with the red laser had a lesser effect on the emergence of seedlings and the first roots in the species of Poaceae plants.

The research of the effect of the combination laser radiation of seeds on growth parameters of plants allowed us to make conclusions about the ambiguity of the reaction response of plants assessed in this experiment. Thus, when assessing *T. aestivum* the height of the above ground part does not undergo probable changes in almost all variants of radiation of seeds (Figure 1). Along with that combination radiation with the red and the blue laser for 5 seconds each (var. 5) and the blue laser for 10 seconds (var. 7) led to an increase in the height of the above ground parts by 9.5-10.4% compared to control plants. Root length was likely to increase by 17.6-28.6% after radiation with the red laser for 5 and 10 seconds (var. 2 and var. 3) and combination radiation with the red and the blue lasers for 10 seconds each (var. 9), when compared to the plants grown from seeds that were not exposed to the radiation. The effect of the radiation with the blue laser and variants of the combination of red and blue radiation with a low level of red light (5 seconds, var. 4, 6, 7 and 8) resulted in a decrease in the root length by 20.0-23.5% compared with the control plants.

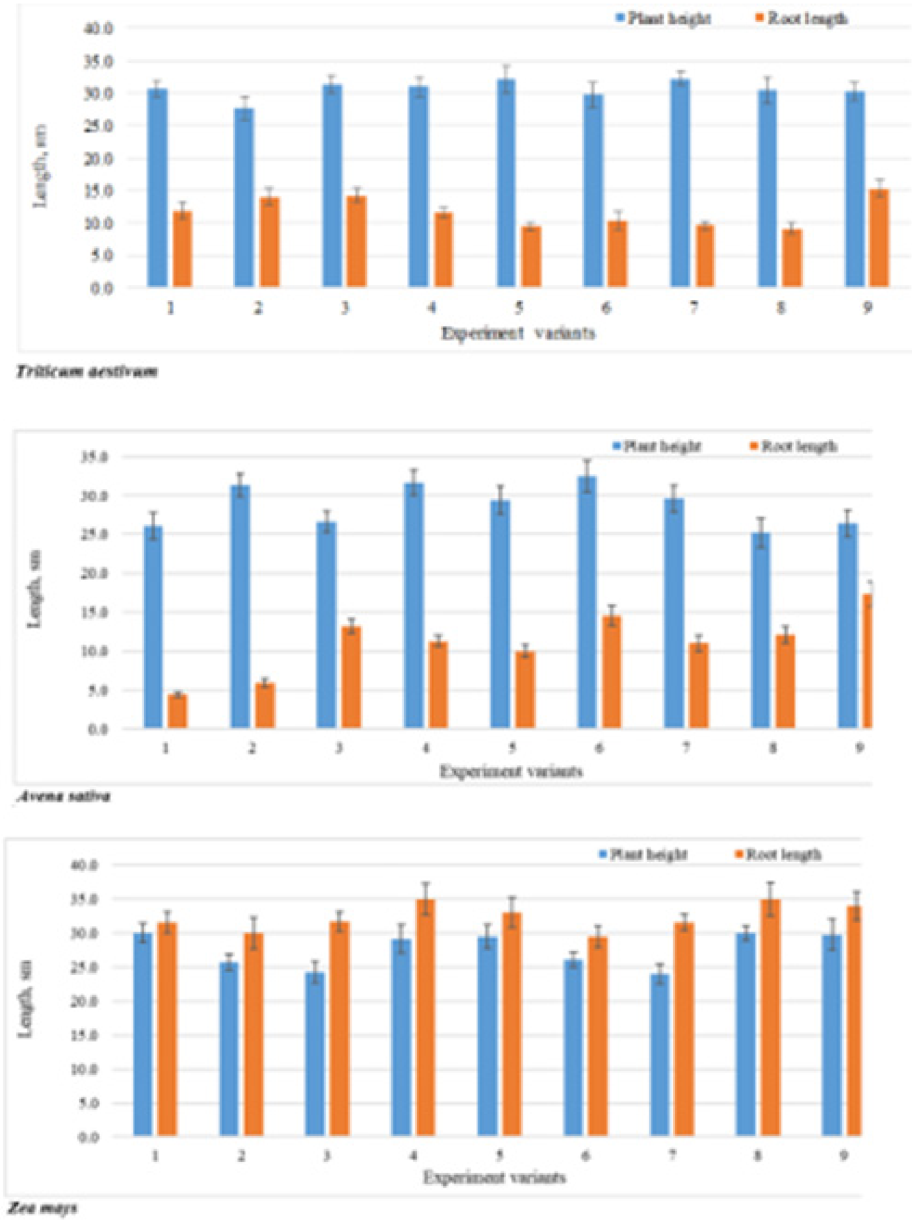

Figure 1: The effect of the combination laser radiation of seeds on growth parameters of plants (variants of the experiment according to Table 1).

In the case of A. sativa, radiation of seeds positively influenced the growth of plants for virtually all combinations of red and blue coherent monochromatic light. The most substantial positive effect was observed with the use of the combination of red laser radiation for 10 seconds and blue laser radiation for 5 seconds (var. 6). Under these conditions, the height of the above ground part was 124.5% of the corresponding index of the control plants. Deepening of root systems in all variants of the experiment significantly exceeded the same index of plants grown from non-radiated seeds. So, after the radiation with the red laser for 5 seconds, this indicator was 34% higher than control plants. In other variants, the length of the roots exceeded the corresponding parameter of the control plants (2.3-3.9 times).

The radiation of *Z. mays* seeds had the smallest effect on growth parameters. In particular, it had almost no influence on the growth parameters of the above ground part in any given variant of the experiment, although the combined effect of the red (5 seconds) and the blue (5 and 10 seconds; var. 5 and var. 8) lasers showed a slight decrease in this indicator. The root systems were not susceptible to the effect of radiation of the seeds with the red laser (var. 2 and var. 3). However, radiation with the blue laser for 5 and 10 seconds (var. 4 and var. 7) and combination radiation (var. 8 and var. 9) caused a probable increase in the root length of 16.1-23.3% compared with the control plants.

Results of this experiment show that radiation of the *T. aestivum* seeds with red monochromatic light caused an increase in the content of chlorophyll a by 27.4-37.5%, and chlorophyll b by 38.4-39.4%, depending on the duration of radiation. The effect of the blue light and combination radiation had a lesser outcome. Thus, after exposure to the blue laser, the chlorophyll a content in plant leaves increased by 4.5-28.6%, while the chlorophyll b content increased by 12.2-14.2% compared with the control plants. After combination radiation with the red and blue light (var. 5, 6, 8 and 9), the content of pigment increased in different experiment variants at 1.1-1.3 times compared with its quantity in plants grown from non-radiated seeds.

The most substantial influence on the chlorophyll content in the *A. sativa* leaves was caused by radiation with the red laser (var. 2 and var. 3). Under these conditions, the amount of chlorophyll an increased by 28.9-44.4 %, and the amount of chlorophyll b increased by 30.0-55.0% compared with the control plants. The combination radiation of seeds with the red and blue lasers at the maximum dose (var. 9) had a significant influence as well. The amount of chlorophylls a and b in plants in this variant of exposure was 122.2 % and 125.0 % compared with the control plants.

The laser irradiation had a positive effect on chlorophyll content in all plants in this experiment with almost all doses and combinations of monochromatic coherent light (Figure 2). *Z. mays* plants were characterized by the strongest response to the five-second radiation with the red laser (var. 2), the blue laser (var. 4) and the combination radiation (var. 8 and var. 9). The content of chlorophyll in the leaves of plants grown from radiated seeds in these variants exceeded the same index of the control plants by 1,4-1,8 times. Other variants of the radiated seeds had a less significant effect on the content of pigments in the leaves of the plants under experiment.

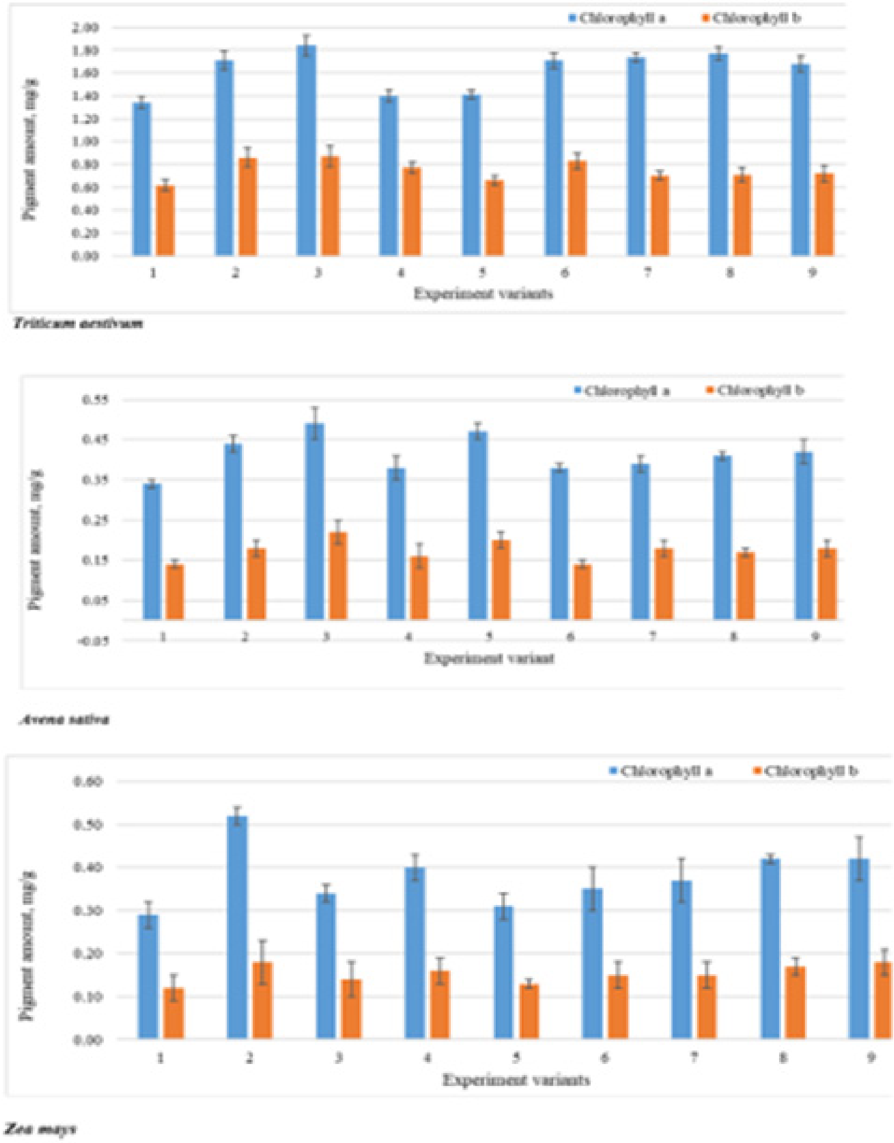

Figure 2: The effect of combination laser radiation of seeds on the chlorophyll content in plants in this experiment (variants of the experiment according to Table 1).

Conclusion

The obtained results allow to make a conclusion about the positive effect of laser radiation with wavelengths of 405 and 635nm on the physiological and growth parameters of selected Poaceae plants in this experiment. It was found that the germination readiness and germinating ability of the plant species increased by 1.5-14.6%. The root emergence was accelerated during germination. The height of the above ground part of the plants and the length of their roots increased by 9.5-23.5%. The amount of green pigment in leaves rose by 22.2-50.0%. The data obtained by means of this experiment and the results of other researchers [27-29] indicate the high efficiency of lasers in stimulating plant development, which reduces the risk of chemical contamination with artificial plant growth stimulators [30-33].

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