ISSN 0018-1439, High Energy Chemistry, 2023, Vol. 57, No. 4, pp. 305–308. © Pleiades Publishing, Ltd., 2023.
Russian Text © The Author(s), 2023, published in Khimiya Vysokikh Energii, 2023, Vol. 57, No. 3, pp. 267–270.

PHOTOCHEMISTRY

Effect of Subdoses of Ultraviolet B Radiation on the Crop Yield of Spring Wheat (*Triticum aestivum* L.)

E. N. Surnina[a, *], **A. A. Burenina**[a], **T. P. Astafurova**[a], **S. I. Mikhailova**[a], **E. A. Sosnin**[a, b], **T. S. Pak**[a], **V. A. Panarin**[b], **and S. A. Nuzhnykh**[a]

[a] *National Research Tomsk State University, Tomsk, 634050 Russia*
[b] *Institute of High Current Electronics, Siberian Branch, Russian Academy of Sciences, Tomsk, 634055 Russia*
**e-mail: ensurnina@mail.ru*

Received December 21, 2022; revised January 11, 2023; accepted January 12, 2023

Abstract—Long-term field studies of the effect of presowing seed treatment of spring wheat (*Triticum aestivum* L.) with XeCl-excilamp UVB radiation on sowing qualities of seeds and plant productivity have been carried out. The features of morphogenesis at various stages of growth and development of wheat plants have been determined. A subdose of exposure has been identified that increases the crop yield. The studies prove the prospects of introducing UVB treatment into the pool of modern agricultural technologies.

Keywords: *Triticum aestivum* L., hormesis, presowing seed irradiation, UVB radiation, morphogenesis, crop yield, grain quality

DOI: 10.1134/S0018143923030141

INTRODUCTION

It is known that the effect of one or another stressor on biological objects depends significantly both on the object itself and on the nature and dose of the acting factor. Moreover, the dose dependence of the effect is nonmonotonic. This was first noticed by Chekhov and Zamaraeva [1], who exposed plant (wheat, legumes, barley) seeds to X-ray radiation and found that when the dose is reduced to moderate values (the so-called subdose), the unfavorable physical factor, on the contrary, has a stimulating effect on the plants. Subsequently, this phenomenon, caused by the action of any stressor, was called hormesis [2]. Currently, hormesis is interpreted as a biphasic dose–effect relationship, in which subdoses of the active factor have a stimulating (positive) effect on the biological object and high doses of the factor have an inhibitory effect [3]. At present, the term “priming” or chilling is also used to refer to this phenomenon [4].

Hormesis manifests itself through both chemical and physical factors of influence [5]. In our experiment, we will consider the hormesis phenomenon for the case when the acting factor is ultraviolet B radiation ($290 < \lambda < 320$ nm) or UVB radiation. In the total radiant flux, its share under natural conditions of solar illumination of the Earth’s surface is no more than 1.5% [6]. In fact, this means that planet surfaces receive a subdose of UVB radiation, having made the basis of E.A. Sosnin’s hypothesis formulated in 2003 that such an impact can be effective for the development of plants. Subsequent testing of the hypothesis on various crops confirmed its validity both for seeds of various crops (flax, cucumbers, wheat, lettuce) and for seedlings and cuttings (grapes, apple, cedar) of plants [7–11].

Previously, we reported on the data obtained in the previous stages of research [9]. In this paper, we summarize the results of the final cycle of field research on the impact of UVB radiation on wheat productivity, which will allow us to speak about reliable and reproducible hormesis by UVB radiation subdoses.

EXPERIMENTAL

A field study to examine the effect of a single presowing treatment of seeds with low-dose UVB radiation on the growth, development, and productivity of wheat was conducted in the collection nursery of the laboratory of agricultural plants on the territory of the educational-and-experimental site of the Siberian Botanic Garden at the Tomsk State University (Tomsk). According to long-term observations, the climate of the Tomsk oblast is sharply continental, with humid, moderately warm summers and long, cold, snowy winters. It is characterized by late spring and early autumn frosts, limiting the already short vegetation period of plants. The weather conditions of the growing season in 2022 are characterized as moderately humid and moderately warm. The sum of active temperatures above +10°C from May to September is 2032.4°C, the sum of precipitation for this period is 278.9 mm. The Selyaninov hydrothermal coefficient

Table 1. Effect of UVB radiation on wheat grain yield by years

Year	Grain yield, g/m^2		
	control	0.5 J/cm^2	% to control
2019	329.58 ± 8.44	363.18 ± 8.06*	110
2020	245.61 ± 6.28	258.31 ± 10.57	105
2021	440.67 ± 38.75	496.11 ± 10.92*	112
2022	249.44 ± 10.42	298.02 ± 7.84*	119

The asterisk * marks significant differences at $p \leq 0.05$.

(HTC) was 1.38, which characterizes the growing season as moderately humid and moderately warm [12].

The object of the study was seeds of soft spring wheat (*Triticum aestivum* L.) cv. Iren. Before sowing, the seeds were treated once with XeCl excilamp (model BD_P) for 120 and 60 s, which corresponded to energy fluences (doses) of 0.5 and 0.25 J/cm^2. An excilamp based on working XeCl* molecules was developed at the Laboratory of Optical Radiation of the Institute of High Current Electronics, Siberian Branch of the Russian Academy of Sciences (Tomsk) and provided an intense emission band in the wavelength range $\lambda \sim 290$–320 nm with an emission maximum at $\lambda = 308$ nm and a band width at half maximum of $\Delta\lambda_{1/2} = 1.9$ nm [13]. Seeds that were not exposed to UV radiation were the control. The seeding rate was 600 pieces/m^2. For each variant, plots with an area of 1 m^2 were laid in 4 repetitions. Observations on the growth and development of plants were carried out throughout the entire growing season from germination to full maturity (ripeness).

To assess the influence of UV radiation on the plant vegetation processes, morphometric parameters (plant height and weight of the aerial part) were evaluated for all samples. The area of wheat leaves was determined from the linear dimensions of the leaf multiplied by the correction factor (for wheat, 0.67) [14]. To determine the dry weight, the seedlings were dried in an oven at 70°C to constant weight. The specific leaf area (SLA) was calculated as the ratio of the dry weight of leaves to their area. Grain quality was determined on an Infralum FT-10 infrared spectrophotometer (Russia).

RESULTS AND DISCUSSION

The conducted long-term studies have shown that presowing treatment of seeds with UVB radiation has a positive effect on the yield of wheat grain, which is the main indicator of plant productivity. Meteorological conditions over the years of the study were different in terms of temperature regime and soil moisture content, which made it possible to comprehensively study the effect of UV radiation subdoses. Analysis of the data for four years of testing showed that the grain yield at a dose of 0.5 J/cm^2 exceeded the control from 5 to 19% (Table 1).

In market conditions, it is important to obtain high yields in combination with grain quality. Main quality indicators are protein, which determines the nutritional value of grain, and gluten, which determines the baking quality of flour by its content. According to published data, environmental factors, growing season conditions, and hereditary characteristics of varieties, as well as the interaction between them, are known have a significant impact on grain quality [15]. Our studies have shown that seed treatment with UV radiation did not affect the quality of wheat grain. The protein and gluten content in different years of field studies did not significantly differ from the control and varied from 12 to 15% (protein) and from 22 to 29% (gluten).

Further studies were aimed at examining and comparing the effect of even lower doses of UVB radiation on the potential productivity of wheat in terms of morphometric parameters. A kind of relationship was revealed in our earlier study [16] on the effect of low doses of X-ray irradiation in pulse-periodic mode on seed quality and wheat productivity. So, having reduced the UV radiation dose by half (to 0.25 J/cm^2), we observed an increase in both the plant height and the mass of the aerial part, which were greater than the control almost throughout the entire growing season, the maximum values of the aerial part mass in the flowering phase exceeded the control by 34% (Fig. 1). The accumulation of biomass in the flowering phase was mainly due to the growth of stems and ears. In the experimental variant of 0.5 J/cm^2, an increase in plant height was also noted in the booting and heading phases, and the above-ground mass exceeded the control at all stages of ontogenesis.

In the plant world, the individual size and mass growth rate of individual plants correlate more closely with the area of leaves than with the intensity of their functioning [17]. Figure 2a shows how the area of the leaves increases proportionally to the aerial part (Fig. 1b), the highest values are noted in the booting phase, then, due to the death of the lower leaves, the total area of the assimilating plant surface decreases. Thus, a tendency to an increase in the leaf area was noted for the 0.5 J/cm^2 variant in the booting phase and the leaf area in the flowering phase exceeded the control by 36% in the 0.25 J/cm^2 variant.

An important parameter of the leaf apparatus, which characterizes the vital activity of plants, is the leaf mass per area (LMA). Some morphological parameters of leaves are closely related to the intensity of photosynthesis and LMA. It was found that LMA

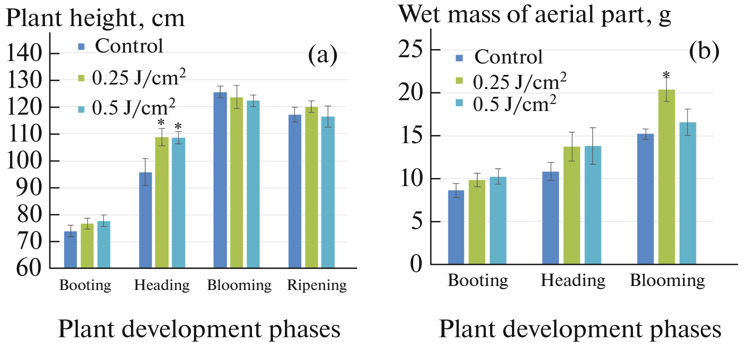

Fig. 1. Influence of the XeCl-excilamp fluence on the (a) plant height and (b) wet weight of the aerial part of wheat. *Significant differences between control and experiment at $p \leq 0.05$.

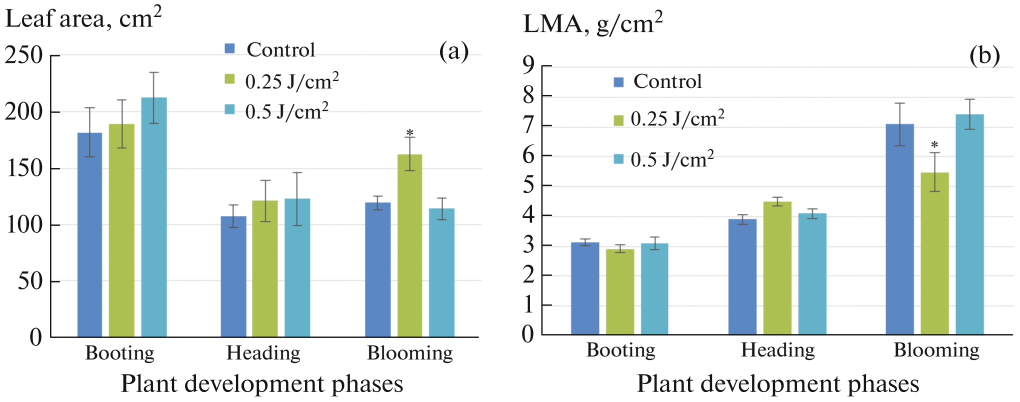

Fig. 2. Influence of the XeCl-excilamp fluence on (a) the leaf surface area and (b) LMA of wheat (2022). *Significant differences between control and experiment at $p \leq 0.05$.

values in the booting and heading phases in all variants were similar and increased during ontogenesis; in the flowering phase, the values were 7.1 and 7.4 mg/cm^2 for the control and the 0.5 J/cm^2 variant, respectively, and LMA decreased to 5.49 mg/cm^2 in the 0.25 J/cm^2 variant (Fig. 2b). It is believed that in plants with a low LMA, with a thinner leaf, photosynthesis is more efficient due to a decrease in the consumption of light energy for leaf formation and its loss [18].

Field studies in 2022 showed that the grain yield in the experimental variants of 0.25 and 0.5 J/cm^2 was 289.1 and 298.0 g/m^2, exceeding the control values by 15.9 and 19.5%, respectively, while grain quality did not decrease: the protein content in all variants was 15%, and the gluten content changed insignificantly, from 28.8 to 29.8% (Fig. 3).

Thus, the presowing treatment of wheat seeds with UVB radiation had a stimulating effect on the morphogenesis and productivity of wheat plants cv. Iren. Switching to lower radiation doses (0.25 J/cm^2) intensifies the development of plants and does not reduce crop yields (within the measurement error). From a scientific point of view, the facts revealed confirm the phenomenon of hormesis in our case. On the practical side, these facts should be taken into account when designing equipment for presowing seed treatment.

CONCLUSIONS

The results of this work confirmed the possibility that low doses of ultraviolet B radiation of a XeCl excilamp have a stimulating effect on wheat seeds. Single treatment of seeds with subdoses of 0.25 and 0.5 J/cm^2 enhanced morphometric parameters, such as plant height, the mass of aerial parts, and the area of the assimilating leaf surface. The yield of wheat under the influence of subdoses of UVB irradiation over four years of field research increased on average by 11.5% without decline in grain quality.

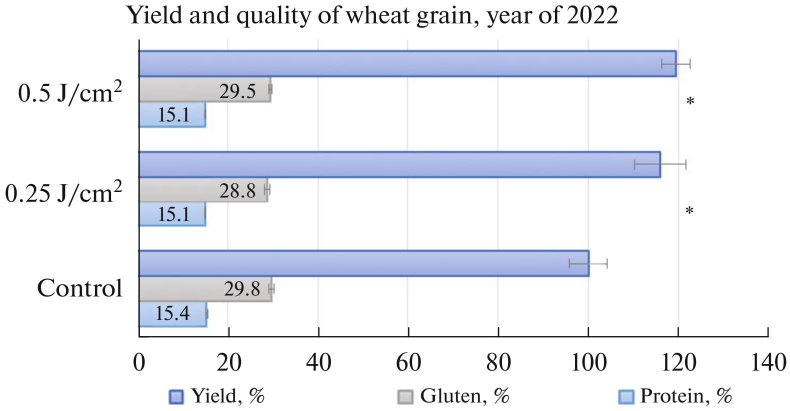

Fig. 3. Effect of UVB radiation on the yield and quality of wheat grain, 2022. *Significant differences between control and experiment at $p \leq 0.05$.

FUNDING

The study was supported by the Development Program of Tomsk State University (Priority-2030) and partly within the framework of State Assignment of the Institute of High Current Electronics SB RAS, project no. FWRM-2021-0014.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Chekhov, V.P. and Zamaraeva, I.K., *Tr. Tomsk. Gos. Univ.*, 1932, vol. 85, p. 23.
2. Southam, C.M. and Ehrlich, J., *Phytopathology*, 1943, no. 33, p. 517.
3. Eidus, L.Kh., *Biophysics*, 2005, vol. 50, no. 4, p. 607.
4. Thomas, D., Jos, T.T., and Puthur, T., *Environ. Exp. Bot.*, 2017, vol. 138, p. 57.
5. De Sousa, AraujoS., Paparella, S., and Dondi, D., *Front. Plant Sci.*, 2016, vol. 7, p. 646.
6. Caldwell, M.M., Teramura, A.H., and Tevini, M., *Trends Ecol. Evol.*, 1989, vol. 4, p. 363.
7. Bender O.G., Petrova E.A., Zotikova A.P., et al., *Vestn. Tomsk. Gos. Univ.*, 2006, no. 67, p. 15.
8. Sosnin, E.A., Chudinova, Y.V., Victorova, I.A., and Volotko, I.I., *Proc. SPIE (XII International Conference on Atomic and Molecular Pulsed Lasers)*, 2015, vol. 9810, 98101K.
9. Sosnin, E.A., Lipatov, E.I., Skakun, V.S., et al., *Prikl. Fiz.*, 2020, no. 2, p. 98.
10. Bayanov, E.O., Fadeeva, Yu.Yu., Lyashcheva, L.V., et al., *Innovatika-2021: Sbornik materialov XVIII Mezhdunarodnoi shkoly-konferentsii studentov, aspirantov i molodykh uchenykh (21–22 aprelya 2022 g)* (Innovatika-2021: Proceedings of XVIII International School—Conference of Students, Postgraduates, and Young Scientists (April 21–22, 2022)), Soldatov, A.N., Ed., Tomsk: STT, 2022, p. 126.
11. Lyashcheva, L.V., Sosnin, E.A., Lyashchev, A.A., et al., *Izv. Orenburgsk. Gos. Agr. Univ.*, 2022, no. 4 (96), p. 179.
12. Weather and Climate. http:www.pogodaiklimat.ru. Accessed December 6, 2022.
13. Sosnin, E.A., Tarasenko, V.F., Panarin, V.A., et al., RU Patent 139005, 2014.
14. Grodzinskii, A.M. and Grodzinskii, D.M., *Kratkii spravochnik po fiziologii rastenii* (A Quick Reference Guide to Plant Physiology), Kiev: Naukova Dumka, 1973.
15. Bedenko, V.P., *Fotosintez i produktivnost' ozimoi pshenitsy na yugo-vostoke Kazakhstana* (Photosynthesis and Productivity of Winter Wheat in the South-East of Kazakhstan), Alma-Ata, Nauka, 1976.
16. Burenina, A.A., Astafurova, T.P., Surnina, E.N., et al., *High Energy Chem.*, 2021, vol. 55, no. 4, p. 324.
17. Poladova, G.G., *Agr. Nauka*, 2011, no. 12, p. 13.
18. Vasfilov, S.P., *Biol. Bull. Rev.*, 2012, vol. 2, no. 3, p. 238.

Translated by S. Zatonsky