PROCEEDINGS

2020 7th International Congress on Energy Fluxes and Radiation Effects (EFRE)

Tomsk, Russia, September 14 – 26, 2020

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7th International Congress on Energy Fluxes and Radiation Effects (EFRE) - 15th International Conference on Modification of Materials with Particle Beams and Plasma Flows - Tomsk - 2020

Influence of UV Radiation and Discharge Plasma on Feed Wheat Seeds for Acceleration of Plants

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***Abstract*—In a rapidly changing unstable climate, the possible acceleration of plant growth and ripening is critical to food security in at least the region. This problem is especially relevant for areas with risky farming, which includes almost all of Siberia, and the Tomsk region in particular. Here we present the next results of a study of the effect of UV and ionizing radiation on cereals, namely, Iren wheat.**

***Keywords*—ionizing radiation, ultraviolet radiation, growing season, wheat.**

I. INTRODUCTION

For farmers, climate has always been a real problem, the solution of even parts of which is always fraught with great financial difficulties and labor costs. At the same time, there remains the risk of not a return on investment. In agriculture, there are many approaches to some extent that facilitate the work of farmers. But under the conditions of observed climate change, many of the methods developed over decades are no longer justifying themselves. Here, breeding work with plants, their gene modification and increase in the growing season due to the construction of greenhouse complexes show themselves in the best way. Unfortunately, selection usually takes several years and even decades of rigorous work. The population is genomically modified with great suspicion and the construction and maintenance of greenhouse complexes is very financially expensive and is not suitable for growing many plants. A search for new solutions is needed. One possible method is to reduce the ripening time of plants.

As studies of recent decades have shown, the acceleration of plant growth and ripening is best affected by irradiation of seed with UV radiation in the range of 300–350 nm [1–5]. But here a technical problem arises. In the laboratory, the results are very encouraging. But under the conditions of a granary, the quality of irradiation noticeably decreases, since dust settles on UV lamps, forming a carbon deposit that does not transmit radiation and additional ventilation does not always save the situation.

An alternative method is to irradiate plant seeds with ionizing radiation, which leads to disinfection (beneficial effect) and destruction of the embryo (adverse effect) [6]. At the same time, the prolonged exposure to ionizing radiation, for example, on cereal seeds, changes the chemical composition of grain, impairs its nutritional quality. But despite the great interest in the world in the radiation effect on various cultivated plants, and the increase in research intensity, a lot remains unknown.

In 2018, experiments were conducted at the Laboratory of Plasma Emission Electronics (IHCE SB RAS) on the effects of a low-energy electron beam on barley seeds.

The study showed that when exposed to radiation with a dose of 1–5 kGy. Along with radisidation, the growth of roots of barley seeds was stimulated. And at a dose of 8 kGy, plant growth is inhibited [7]. But from the literature it is known that inhibition of plant growth occurs already at a dose of 1 kGy. As a rule, stimulation of plant growth by ionizing radiation is carried out with a dose in the range of 0.003–0.05 kGy [8]. The peculiarity of the work [7] was that the electron accelerator with a plasma cathode was used to irradiate the grain, the beam energy in which does not exceed 200 keV. This allows high-quality processing of the grain surface without killing its embryo.

This paper presents the comparative results of a study of the effect of pretreatment of wheat seeds of the variety Iren with UV radiation and ionizing radiation on its subsequent growth and ripening. These experiments were carried out in the field and are preliminary to identify further areas of research.

The work was performed in the framework of the State task for IHCE SB RAS, project #13.1.4.

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II. EXPERIMENTAL SETUP

Seed pretreatment was carried out at two experimental setup. In the first experimental setup [9], used by us for several years (Fig. 1), the grain was irradiated with UV radiation from an XeCl excilamp (λ = 308 nm). The radiation doses were 1.26 J/cm^2, 3.15 J/cm^2, 4.41 J/cm^2. At the same time, part of the grain was processed 7 days, and part 1 day before sowing. The irradiation part of the setup consists of a XeCl excilamp of a barrier discharge (*1*), where the external electrode (*2*) is made of reflective foil and the internal (*3*) is wound from wire. Due to this, radiation from the region of the barrier discharge (*4*) propagated into the internal volume of the lamp, where grain was supplied through the screw mechanism (*5*).

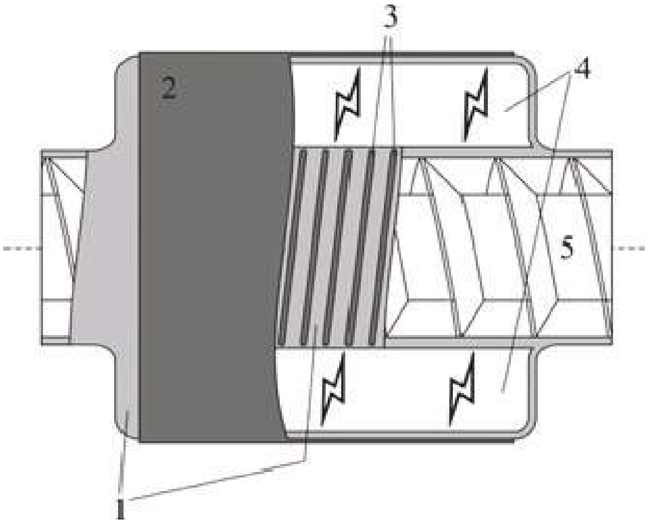

Fig. 1. Scheme of equipment for presowing UV treatment of grain seeds. 1 – quartz flasks, which are the walls of the XeCl excilamp, 2 – a reflecting electrode of metal foil, 3 – a translucent electrode of metal wire, 4 – the region of the pulsed barrier discharge in the Xe-Cl2 mixture, 5 – polymer (polyamide) screw for feeding grain.

Scheme of setup accelerator "Duet" [10] for grain processing by ionizing radiation is presented in Figure 2. Here wheat was treated with radiation with doses of 5 and 10 kGy. As in the previous case, part of the grain was processed 7 days, and part 1 day before sowing. The installation is a vacuum chamber (*1*) separated from the external environment with foil (*2*). Inside is a plasma emitter (*3*), consisting of a hollow anode (*4*), a cathode (*5*) and an ignition electrode (*6*). Electrons from the plasma of an arc discharge through the emission grid (*7*) and foil (*2*) were removed outside the chamber, and acted on the grain located in the cell (*9*).

During the exposure, part of the grain was turned over and processed repeatedly with the same dose. Thus, as a result of processing, the samples for sowing were obtained, are presented in table 1.

Each of the samples was divided into two equal parts, which were planted in different parts of the field. It should immediately be noted that wheat growth occurred in extreme conditions. Firstly, the sowing was carried out in the virgin land, without many years of preliminary soil preparation. Firstly, the sowing was carried out in the virgin land, without many years of preliminary soil preparation. Secondly, the sowing work was carried out with a delay of one month (June 11, 2019) from the start of sowing in the region.

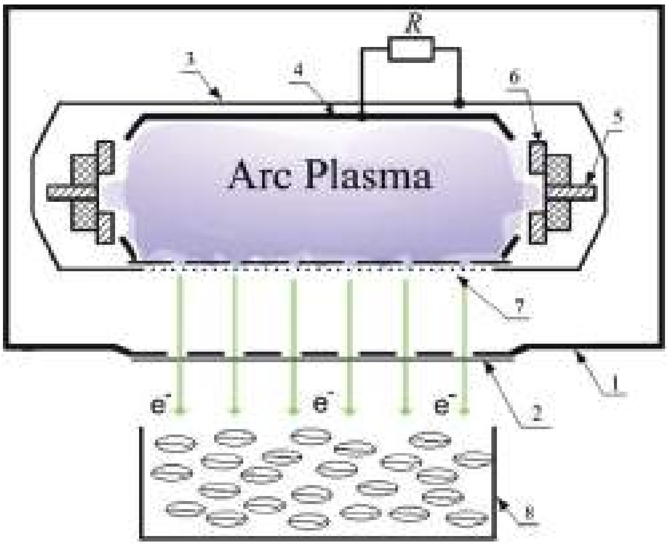

Fig. 2. Scheme of the setup "Duet": 1 – vacuum chamber, 2 – foil, 3 – plasma emitter, 4 – hollow anode, 5 – cathode, 6 – ignition electrode, 7 – emission grid, 8 – cell with grain.

TABLE I. PROCESSING MODES FOR SAMPLES FOR SOWING

UV treated grain		
Dose, J/cm^2	1 day	7 days
0 (Control)	*	*
1.26	*	*
1.89	*	*
3.15	*	*
4.41	–	*
Grain treated with ionizing radiation		
Dose, kGy	1 day	7 days
5	–	–
5 (twice)	*	*
10	*	*
10 (twice)	*	*

For these reasons, one should not talk about any crop. However, one can get an idea of the relative values, since both the control and radiation-treated samples were under the same conditions.

Grain was collected from each of the plots from 1 m2 on September 1, 2019. Thus, the vegetation time was artificially reduced to 82 days.

III. RESULTS AND DISCUSSION

As a result, the following data were obtained.

From the graphs of Figure 3 it can be seen that the grain mass fluctuates around 20–30 mg, while it is noticeable that the seeds planted immediately after irradiation produced more massive grains than those that were planted with a delay of 7 days. It can also be noted that treatment with UV radiation with a dose of 3.15 J/cm^2 and higher did not contribute to an increase in the mass of grains relative to the control sample. The impact of ionizing radiation had little effect on the increase in mass of grains relative to the control sample.

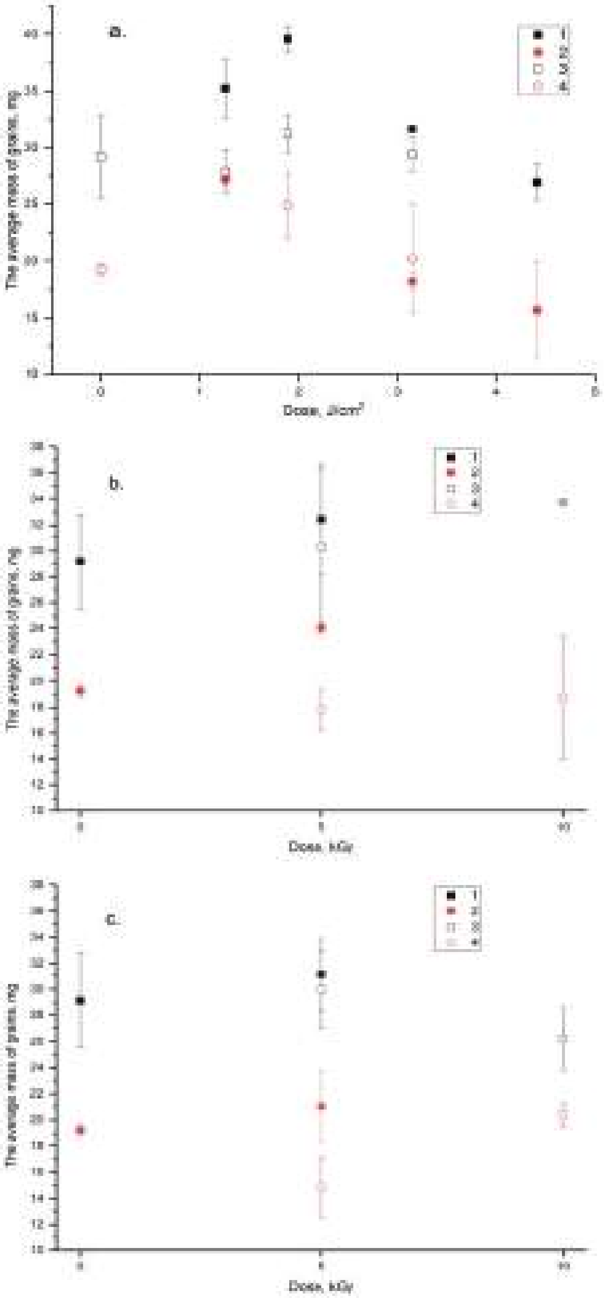

Fig. 3. The average mass of grain in the harvested crop: a) – after preliminary irradiation with an XeCl excilamp. b) – after a single exposure to the setup "Duet", c) – after double exposure on the setup "Duet". 1 – ripened grain from areas where sowing was done 1 day after irradiation, 2 – unripe grain from the same sites, 3 – ripened grain from sites where sowing was 7 days after irradiation, 4 – unripened grain from the same areas.

Figure 4 shows that the mass of ripened grain relative to the total mass collected from the plots is 60% and does not differ in this value from the control, with the exception of two samples where there wasn’t no ripened grain. When the electron accelerator was used for irradiation, the relative mass of ripened grain was also about 60%, regardless of the post-radiation period and the processing method (from one or both sides). Most likely, this indicates that the experimental conditions and climatic conditions influenced the germination more than the radiation. At the same time, the data obtained also confirm the prospects of using such pre-sowing treatment, if not for stimulation, then for disinfection of grain.

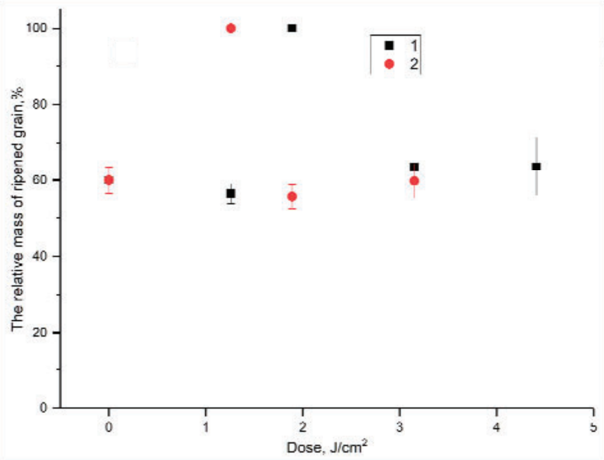

Fig. 4. The mass of ripened grain relative to the total amount collected from the site after treatment with UV radiation: 1 – from the areas where the sowing was done 1 day after the radiation treatment, 2 – from the areas where the sowing was done 7 days after the irradiation.

The amount of ripened grain (fig. 5.) collected from the areas where the treated grain was planted significantly exceeds the control sample. But the greatest advantage was given to those plants whose seeds were treated with UV radiation with doses of 1.26 J/cm^2, 1.89 J/cm^2 and ionizing radiation with a dose of 5 kGy. Already when exposed to doses greater than 3.15 J/cm^2 and 10 kGy, the amount of ripened grain up to the control values. Which speaks not of stimulating growth, but inhibiting the development of wheat seeds.

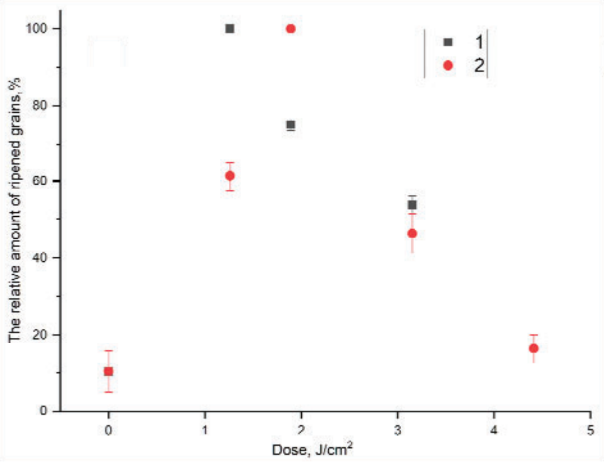

Fig. 5. The amount of ripened grain relative to the total number collected from the plots after treatment with UV radiation: 1 – from the areas where the sowing was done 1 day after the radiation treatment, 2 – from the areas where the sowing was done 7 days after the irradiation.

IV. CONCLUSION

Despite all the difficulties of growth, greater competition from weeds, a significantly reduced vegetation period (only 82 days), Iren wheat showed interesting results.

First, the amount of grain collected from equal-sized sections is at best ~ 6 times greater than the control sample, regardless of the irradiation method. Moreover, despite the large scatter of values, due to the small number of samples, even treatment with ionizing radiation in rather large doses stimulated rather than depressed plant growth.

Secondly, confirming our early studies, UV irradiation with a dose of more than 3.15 J/cm^2 apparently does not have a mass stimulating character. Most likely, in this case, part of the seeds was excessively irradiated and germination was inhibited, and part of the seeds received a stimulating dose. Due to the fact that the seeds, when fed by the screw mechanism, are not distributed on the inner surface of the lamp in a thin layer.

Unfortunately, in this experiment, we were not able to create more representative conditions for plant growth. Nevertheless, in our opinion, the results obtained are of certain interest and more accurately determine the boundaries and direction of further research.

ACKNOWLEDGMENT

The work was performed in the framework of the State task for IHCE SB RAS, project #13.1.4.

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