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Pre-Sowing Stimulation of Wheat with UV-B Radiation of XeCl-Excilamp

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***Abstract*—The share of UVB spectrum range (290-320 nm) in the solar radiation flux accounts for an average of about 1.5% of the radiant flux on the planet. Taking into account the fact that plants adapt to living conditions in the course of evolution, it can be assumed that the flow of UVB radiation is also used by plants, but at the level of subdoses that reach the Earth's surface. The aim of current work is to study the growth and development of spring wheat ("Irgina" cultivar) when treated with subdoses of UVB radiation. For processing, XeCl-excilamp (High Current Electronic Institute SB RAS) radiation was used. The spectrum of this lamp is a narrow band with a maximum at a wavelength of 308 nm, which corresponds well to the UVB range. In the course of study, the pre-sowing UVB radiation dose values for seeds were found, under the influence of which wheat sprouts had an increase in such indicators as the length and dry weight of the root, the length of the leaf and the ratio of the root/shoot masses. It was shown, that as plants developed, the nitrogen balance index was always higher in the experiment with radiation in plants whose seeds were subjected to pre-sowing treatment with UVB radiation. This indicates the activation of growth and development processes in plants, as well as the accelerated absorption and assimilation of nitrogen compounds. Under the action of dose 0.5 J/cm^2 the weighting parameters grain productivity such as weight of grains per ear, spike weight, weight of 1000 pcs seeds and the grain yield exceeded the check by 10.2 %. The UVB processing did not affect the quality of the wheat grain. Based on the obtained data, it is concluded that the use of XeCl-excilamp UVB radiation for pre-sowing stimulation of wheat is promising.**

***Keywords*—crop structure, excilamp, pre-sowing stimulation, XeCl, wheat.**

I. Introduction

In modern plant science are relevant search for ways of seeds dormancy breaking to obtain earlier and good sprouts, laying the basis for increasing the yield, obtaining early and high-quality products. Currently, it has been established that various physical factors, such as plasma, gamma radiation, microwave fields, as well as optical radiation in optimal doses can stimulate seed germination and plant development [1, 2]. In particular, a lot of research is devoted to ultraviolet radiation effect on plants.

The UV range is classified into three sections (UVC or "hard ultraviolet" ($200 < \lambda < 280$ nm), UVB ($280 < \lambda < 320$ nm), UVA or "soft ultraviolet" ($320 < \lambda < 400$ nm). The UVB spectrum range action on plants is scantily known. Its share in the solar radiation flux accounts for an average of about 1.5 % of the radiant flux on the planet [3].

During biological evolution, the living organisms adapt to their environment. Based on this, in 2003, E.A. Sosnin put forward a hypothesis that the subdoses of UVB radiation

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reaching the Earth's surface are also used by plants. In other words, it was assumed that the subdoses of UVB radiation have the property of photoregulation of plants in the early stages of plant development. Our subsequent experiments on coniferous and cultivated plants confirmed this hypothesis [4–10].

Independent studies of the last decade [11] have shown, that the seeds of various plants (rice, maize, cucumber, cowpea etc.) after low dose UV irradiation stimulated the seed germination, growth, biomass, seed coat thickness, fresh and dry weight of roots and shoots. Moreover, the pigment content (chlorophyll, carotenoids) and also the photosynthesis were increased. UV pre-sowing stimulation of seeds also enhanced the activities of antioxidant enzymes and thus enhances tolerance of plants towards various abiotic stresses.

Today, we need not only laboratory, but also field studies that allow us to obtain data on all stages of plant ontogenesis after UVB treatment of seeds. In this paper, we conduct a such study, determining the effect of pre-sowing treatment of seeds with UVB radiation on the process of ontogenesis and the structure of the wheat crop.

II. Materials and Methods

The object of the study was the seeds of soft spring wheat (*Triticum aestivum L.*, «Iren» cultivar), whose seed germination was determined in advance according to GOST 12038-84 and was at least 95 %.

The seeds were irradiated with XeCl-excilamp [12] (BD_P model, Institute of High Current Electronics SB RAS). Figure 1, a depicts the excilamp spectrum. It responds to the edge of the shortwave solar emission. Therefore, XeCl-excilamp might be represented as a simulator of solar short-wave radiation.

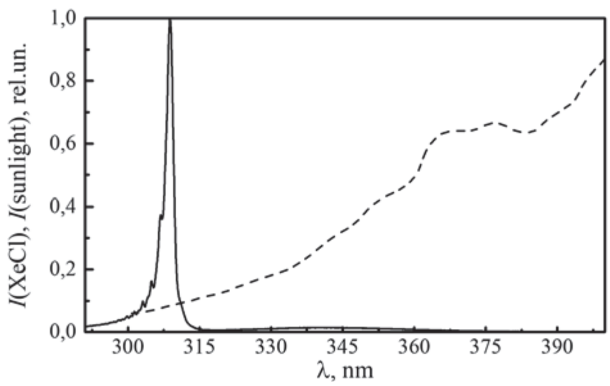

Fig. 1. XeCl-excilamp emission spectrum (solid line) in comparison with solar radiation at sea level (dotted line)

Field studies was carry out in the collection nursery of the Laboratory of agricultural plants, located on the territory of the training and experimental section of the Siberian Botanical Garden of Tomsk State University. The soil of the site (according to the analysis of the station of local agrochemical service) is gray forest, medium-saline, medium-loamy in mechanical composition. Soil availability of mobile forms of phosphorus and potassium is high. The humus content is 3.2 %, the pH of the salt extract is 6.0. Field studies were conducted according to V.A. Dospekhov methods [13].

The predecessor of wheat on this soil were annual grasses. The main tillage (plowing) was performed in autumn to a depth of 20–22 cm. Pre-sowing tillage included early spring harrowing of the soil with tooth harrows. Before sowing, the soil was milled to a depth of 8–10 cm.

Before planting the wheat seeds were treated with XeCl-excilamp radiation. The irradiation doses of wheat seeds in the experiments were 0.5 and 1.4 J/cm^2. These values were found in our preliminary studies [10]. Seeds that were not exposed to UV radiation were used as a check variant. The seeding rate was 600 pieces per 1 m^2.

Morphometric parameters were determined by the length of sprouts and the mass of the aboveground part of plants. To determine the dry weight, the sprouts were dried in a drying chamber at 70°C. The leaf area was measured using the ImageJ program. The net productivity of photosynthesis was calculated using the Kidd-West-Briggs formula [14]. The study of wheat grain quality was carried out on an infra-red spectrophotometer FT-10 (LUMEX LLC, Russia). Measurement of the amount of chlorophyll $a + b$, flavonoids, as well as calculation of the nitrogen balance index were performed on the leaves of living plants using a portable non-destructive testing device Dualex (Forse-A, France).

Statistical processing of research results was performed using Microsoft Office Excel 2013 and Statistica 8.0. the tables show the average arithmetic values in the form "average ± error of the average". Significant differences were determined at the confidence level $p \leq 0.05$.

III. Results and Discussion

Observations on the phenological stages of growth and development of wheat plants were recorded throughout the field study. Sowing was carried out on may 29, the first seedlings appeared on the sixth day after sowing, on the twelfth day the field germination of seeds was recorded (Table 1).

On the 20th day after the sprouting, the onset of the tillering phase was noted. In the first half of July, the next phenophase (booting) was observed. At this phase, crops are very demanding to all growth conditions (heat, light, nutrients and moisture). In the second decade of July (July 11–14) the earing starts. After the earing phase, the flowering came (its duration was 20–25 days). The next period (maturation) is divided into two subphases: ceral and full ripeness. When the grain reached full maturity, the crop was harvested on September 10.

Thus, after pre-sowing treatment of seeds with XeCl-excilamp radiation, during phenological observations, no deviations in the rhythm of plant development from the usual one peculiar to this species were found. The duration of the “sowing to germination” period was 8 days. The beginning of tillering is marked in all variants of the experiment after 20 days from germination. The booting phase came after 31 days from germination and earing phase after 36 days. The “seedling to flowering” period of time lasted 43 days, and the “seedling to maturation” period of time was 96 days.

Photosynthetic processes play an important role in the formation of yield, due to which the bulk of organic matter is formed. One of the indicators of photosynthetic activity of plants is the net productivity of photosynthesis (NPF), which characterizes the accumulation of vegetative mass over a certain period of time. The NPF determination was carried out in the initial stages of ontogenesis, since during this period the accumulation of plant biomass occurs mainly due to the processes of biosynthesis. Plants were analyzed in 4 terms, the period between sampling was 7–9 days. The average data for plant development phases is shown in table 2.

TABLE I. EFFECT OF UVB RADIATION DOSE ON FIELD GERMINATION OF WHEAT SEEDS

Variant	Viability, pieces per m²	Viability, %
Check	399.67 ± 17.07	66.61 ± 2.85
0.5 J/cm²	426.33 ± 14.25	71.06 ± 2.38
1.4 J/cm²	411.33 ± 23.92	68.56 ± 3.99

TABLE II. EFFECT OF UVB RADIATION ON NPF, G/M² PER DAY

Plant development phase	Variant		
	Check	0.5 J/cm²	1.4 J/cm²
Tillering	9.3 ± 0.36	10.7 ± 0.24*	9.5 ± 0.20
Booting	4.6 ± 0.21	4.9 ± 0.16	3.9 ± 0.11

(in the tillering phase), or was less than the check values by 15 %.

It is known that photosynthesis and related indicators reflect the vital state of plants and respond to changes in growing conditions. In our experiment, the content of total chlorophyll ($a + b$) was determined during the growth of wheat plants. The content of pigments was determined in flag leaves, which make the main contribution to the photosynthesis process (Figure 2, a).

It was found that under 0.5 J/cm² UVB-dose, the amount of chlorophyll in all periods of analysis was higher by 9–24 % relative to the check variant. Treatment with a dose of 1.4 J/cm² had a smaller effect on the content of chlorophyll. In the last two periods of measurements, its content increased by 7 and 13 % compared to the check variant.

Flavonoids (plant polyphenols) have antioxidant properties and the ability to neutralize free radicals that occur during oxidative stress [15]. The study of flavonoid content in the leaf epidermis did not reveal significant differences between the experimental and control variants in all study periods (figure 2, b). On the other hand, this result indicate that the treatment of seeds with XeCl-excilamp radiation did not cause oxidative stress and destructive changes in plants.

In the experiment with a dose of 0.5 J/cm², the nitrogen balance index (NBI), calculated as the ratio of chlorophylls to flavonoids, increased at all stages of observations, which indicates, most likely, the activation of growth and development processes in plants and better absorption and assimilation of nitrogen compounds. In the experiment with a dose of 1.4 J/cm², the NBI did not differ from the check variant at different times, except for the last observation period.

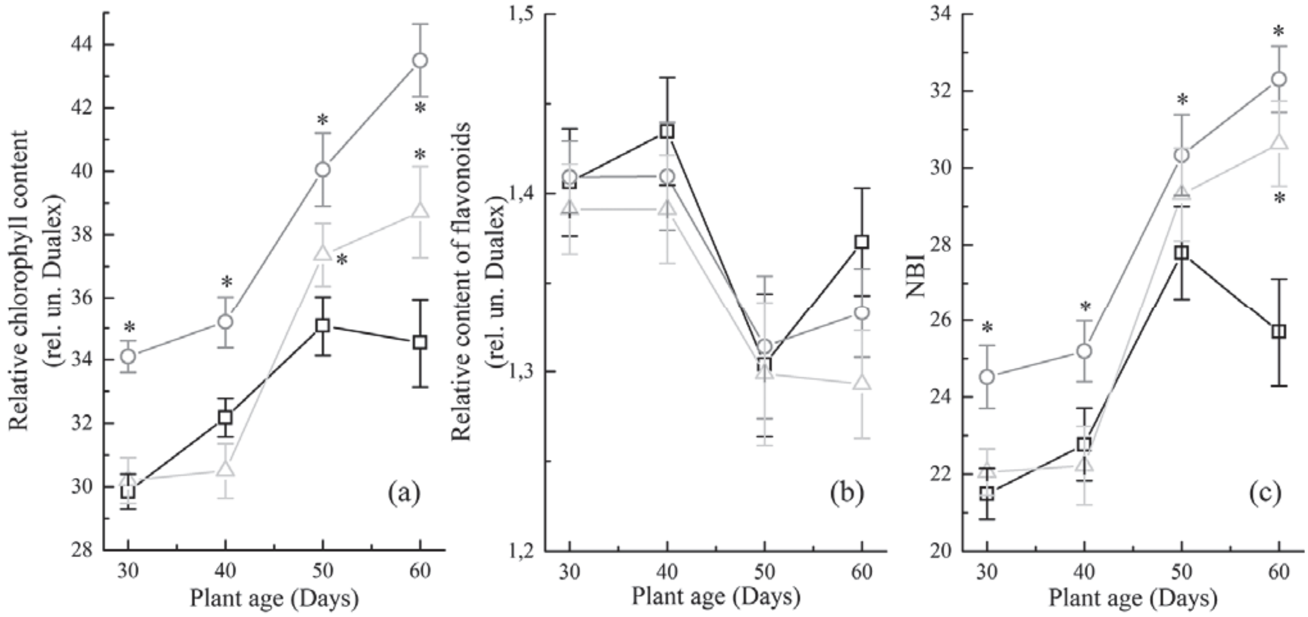

Fig. 2. Effect of UVB on the content of chlorophylls, flavonoids and NBI in wheat leaves: □ – check; △ – 1.4 J/cm²; ○ – 0.5 J/cm². Here and further, the '*' sign marks significant differences between control and experience at $p < 0.05$.

It have shown that the NPF value of both the check and experimental options was higher in the tillering phase, when there was an active accumulation of vegetative mass. In the booting phase the NPF decreased, but during all measurement periods, this indicator in the variant with a dose of 0.5 J/cm² exceeded the check variant by 7–8 %. At the same time, the NPF in the variant with a dose of 1.4 J/cm² either did not differ

Now let's look at the structure of the resulting crop. Under the action of dose 0.5 J/cm² the weighting parameters grain productivity such as weight of grains per ear, spike weight, weight of 1000 pcs seeds and the grain yield exceeded the check by 10.2 %. Under the influence of a dose of 1.4 J/cm^2, all the main indicators of the structure of the wheat crop did not change relative to the check, although there was a tendency to increase them (Table 3).

TABLE III. INFLUENCE OF PPRR ON STRUCTURE OF WHEAT CROP

Plant characteristics	**Variant**		
	Check	0.5 J/cm^2	1.4 J/cm^2
Plant height, cm	93.75 ± 1.37	89.6 ± 1.40*	89.95 ± 1.37
Number of productive shoots	352 ± 11.93	365.7 ± 15.9	361 ± 16
Spike length, cm	8.02 ± 0.17	9.13 ± 0.17*	8.31 ± 0.18
Spike weight, g	1.38 ± 0.08	1.68 ± 0.05*	1.53 ± 0.06
The number of grains per spike	26.44 ± 1.22	31.9 ± 0.94*	28.20 ± 0.84
Weight of grain in the ear, g	1.06 ± 0.06	1.28 ± 0.05*	1.18 ± 0.05
Weight of 1000 pcs seeds, g	38.26 ± 1.22	38.8 ± 0.77	39.1 ± 1.2
Grain yield, g/m^2	329.6 ± 8.44	363.2 ± 8.1*	342.6 ± 13.8

It is important that the UVB pre-sowing of seeds did not affect the quality of the wheat grain. The amount of protein in the grain of the analyzed samples was almost the same and amounted to 12.8 %, and such indicators of grain quality as humidity and vitrescence did not differ significantly from the check variant. Grain moisture varied from 10.16 % to 10.24 %, and vitrescence content from 37.5 % to 38.5 %. The gluten content changed slightly from 20.6 % to 21.5 %. The quality of gluten is also important, which is characterized by the index of gluten deformation (IGD). At a dose of 0.5 J/cm^2, the highest IGD value was obtained (74.73 units), and the lowest in the check variant (73.34 units).

IV. CONCLUSION

Thus, after pre-sowing treatment of seeds with XeCl-excilamp radiation with dose of 0.5 J/cm^2, the indicators of the wheat crop structure (grain yield, number of grains in the ear, length and weight of the ear) significantly exceeded the check variant by 10.2 %.

It is important that the effect of stimulation is observed after a single exposure in small doses and does not reduce the quality of wheat grain. Therefore, the effect can be multiplied and spread on the technology, providing a high speed of pre-sowing seed treatment.

Subsequently, it is planned to identify the possibilities of combined pre-sowing treatment of seeds and to tests of other valuable crops to identify their species and variety specificity in relation to radiation.

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