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Effect of acute UV irradiation of barley in different stages of organogenesis on yield

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Abstract. The negative effect of acute barley irradiation depends both on the spectrum of UV radiation and on the stage of plant development. UV-B radiation, having a higher photon energy, has the greater negative effect compared to UV-A radiation at the same dose of irradiation. During the vegetation, barley is the most sensitive to the influence of ultraviolet at the II-V stages of organogenesis (in the transition from the vegetative to the generative stage of development). The adverse effect of UV-B radiation on the grain yield shows in the substantial reduction of flowers in the ear during their laying and probably in the pollen sterility.

1. Introduction

Ultraviolet (UV) radiation occupies a special place among global environmental factors affecting terrestrial ecosystems and, hence, the agrosphere. The decrease in the concentration of stratospheric ozone increases the solar UV radiation influx at the earth's surface and shifts it to a shorter wavelength spectral range. By the end of the 20th century, the reduction of the ozone concentration in the stratosphere over the countries of Europe was about 1% per year [1]. At the present stage of the biospheric phenomena, this tendency can be intensified due to appearance of the "ozone holes" in the winter-spring period, previously not observed in the Arctic. Sharp decreases in stratospheric ozone in the Arctic in spring attracted strong attention to studies of the ultraviolet radiation effect on agricultural plants [2]. In this connection, it became necessary to experimentally study the effects of acute UV irradiation of agricultural agrocenoses.

Particular attention should be given to the study of the sensitivity of plants at different stages of organogenesis, since an increase in the intensity of UV-B radiation due to the formation of "ozone holes" is usually observed in the spring period when the active growth of winter grain crops begins. As can be seen in figure 1, the ozone depletion can be as high as 50% in some cases. For plants in the northern part of Eurasia and Canada, the usual level of ultraviolet radiation is very low during this period because of the low sun position above the horizon. And plants may not have time to adapt to a sharp and short-term increase in UV radiation [3]. Research of the vegetating plants reaction to acute UV irradiation at various stages of organogenesis is necessary to predict crop losses. Therefore, this article is focused on the morphological reaction of barley to acute UV irradiation (A and B) in different phases of organogenesis.

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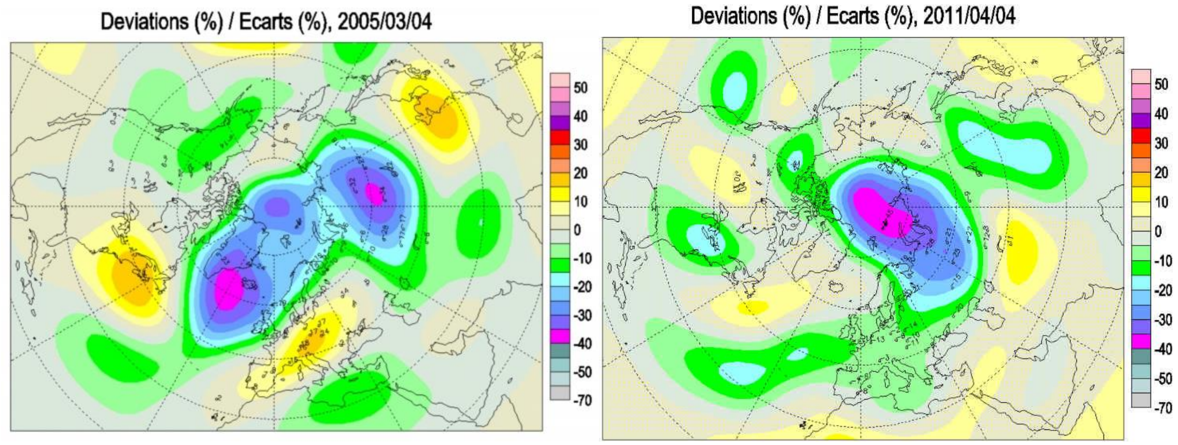

Figure 1. Examples of "ozone holes" in the Arctic [4].

2. Material and methods

The subject of the study was barley (Hordeum vulgare L.) variety Zazersky 85. The plants were grown in vessels containing 4.5 kg of air-dry sod-podzolic soil. Agrochemical properties of soil: pH_{KCl} 5.00±0.01; humus 1.42±0.01%; hydrolytic acidity 2.06±0.03 meq / 100 g soil; the sum of the absorbed bases is 5.75±0.05 meq / 100 g soil; exchange K_2O and mobile P_2O_5 8.52±0.4 and 48.5±1.0 mg / 100 g, respectively. Prior to sowing, nutrients were added to the soil at the rate of N_{200}, P_{100} and K_{100} mg / kg of soil according to the active substance in the form of aqueous solutions of salts (NH_4NO_3, KH_2PO_4 and K_2SO_4).

The irradiation was carried out once when the plants reached certain phases of organogenesis: the third leaf (stage I of organogenesis), the tillering (stage II organogenesis), the outlet into the tube (stage III of organogenesis) and the formation of the lower node of the straw (stage V organogenesis) for 5 hours at a dose rate 5 W/m^2. The total dose was 90 kJ/m^2. As a source of UV-A radiation, Black Light BLUE lamps from Philips, for UV-B — LER-40 (figure 2) were used. Since a decrease in the thickness of the ozone layer to 50%, a significant increase in UV-B radiation is observed only in the range of 295 – 320 nm, and the greatest increase in UV-A in the 320 – 370 nm range (figure 3), in the first approximation can be considered irradiation with these lamps corresponding to the spectrum of acute irradiation due to "ozone holes".

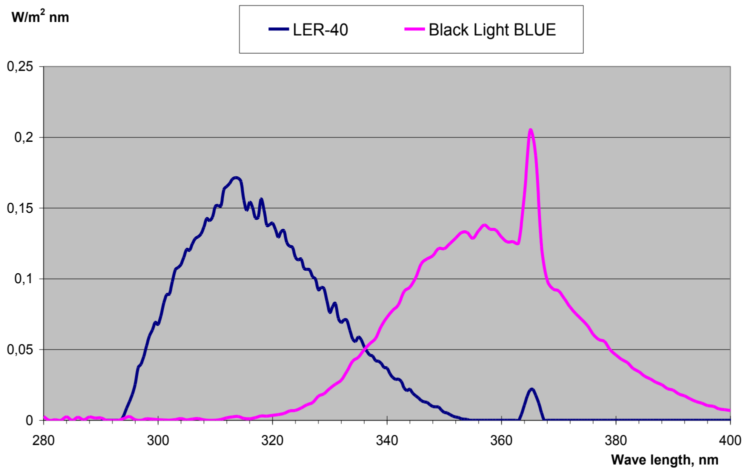

Figure 2. Spectra of LER-40 and Black Light BLUE lamps in the UV range.

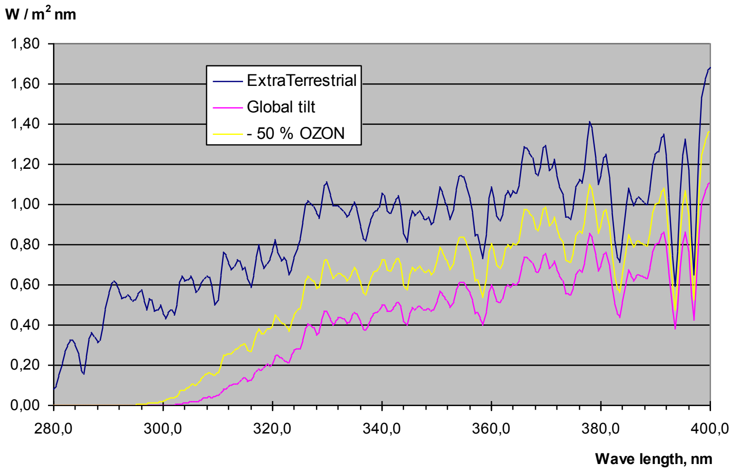

Figure 3. Spectra of solar radiation in the UV range behind the atmosphere, at ground level and at a 50% reduction in the ozone layer.

The effect of the studied spectra of acute UV radiation was estimated at the end of vegetation through the morphological parameters and the grain yield from the plant. The reliability of the differences in the variants of the experiment was established according to the t-test. The text and figures show the mean values and the error of the mean X ± m.

3. Results

The study of the morphological response of barley to acute irradiation of UV-A and UV-B ranges when exposed to various stages of organogenesis showed an ambiguous dependence.

UV irradiation at these stages of organogenesis did not have a negative effect on the barley growth (figure 4). UV-B irradiation at the V stage of organogenesis caused suppression of plant height by 12% ($p < 0.05$). The integral indicator that determines the resistance of plants to various stress factors is the final yield (figure 5), the decrease of which indicates the changes occurring at different levels of the organization of the plant organism and the violation of its most important functions.

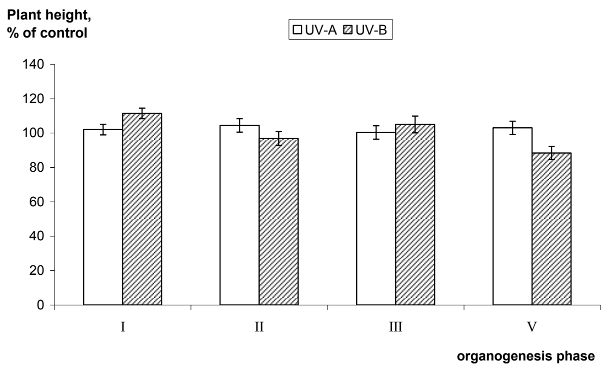

Figure 4. Plant height after acute UV irradiation in different phases of ontogenesis in relation to control.

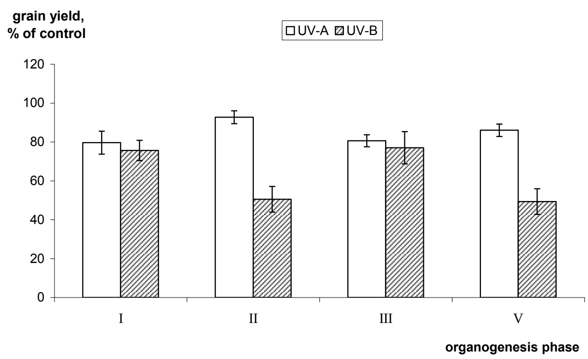

Figure 5. Grain yield after acute UV irradiation in different phases of ontogenesis in relation to control.

As can be seen in figure 5, the greatest yield losses occur when plants are irradiated with UV-B in the phase of formation of additional shoots and in the phase of flower formation. If we consider the effect of acute UV irradiation of barley plants in terms of the additional yield shoots formation on the plant, UV-A irradiation during the first growth period even contributes to their increase ($p<0.05$), while UV-B irradiation significantly reduces the productivity of additional stems in barley plants in any period of development (figure 6). The effect of chronic increased UV-A and UV-B irradiation on the formation of lateral shoots was noted in the other studies [5]. Acute UV irradiation also negatively affects the formation of grain in the ear of plants. In this case, the most pronounced effect is from UV-B irradiation in the phases when the ear (II) is laid and flowers (V) are formed (figure 7).

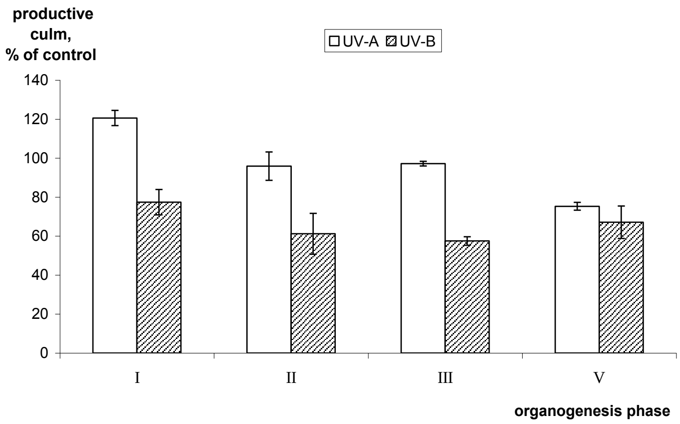

Figure 6. Number of productive shoots per plant after acute UV irradiation in different phases of ontogenesis in relation to control.

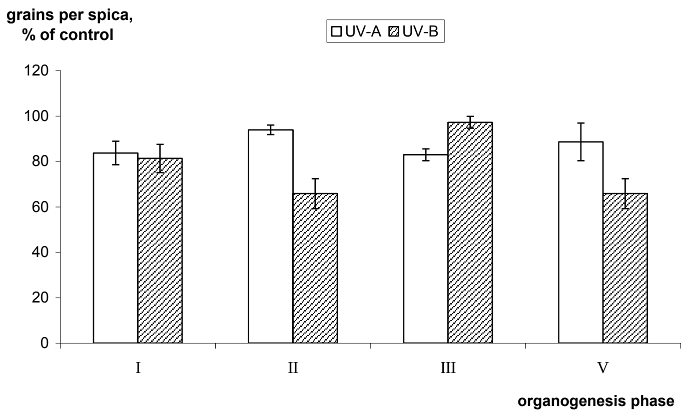

Figure 7. The number of grains in the ear after acute UV irradiation in different phases of ontogenesis in relation to the control.

Thus, as a result of the studies, it was revealed that the UV-B irradiation of plants has more negative influence then UV-A on all morphological parameters studied (plant height, number of productive stems, number of grain in the ear and mass of grain from the plant) during all stages of organogenesis at a total daily dose of 90 kJ/m^2. The negative effect of UV-B radiation was manifested in the formation of productive stems during irradiation at all stages of organogenesis (the decrease amounted to an average of 40%). UV-B irradiation of barley in the II and V stages of organogenesis led to a decrease in the average head spike of an average stem by 34% compared to the control, whereas UV-A irradiation showed no differences from the control for this indicator. UV-B irradiation in the II-V stages of organogenesis also caused a decrease in the mass of each grain by an average of 48%.

The obtained experimental data cannot be used directly to predict the loss of barley yield from acute ultraviolet irradiation, but only to evaluate the most sensitive phases of the development of barley plants in the ultraviolet. In this experiment, separate UV-A and UV-B irradiation was used. However, there are data on the "protective" effect of UV-A radiation relative to the effect of UV-B radiation upon their combined action [6]. It is also necessary to take into account the density of crops, since the effect in photobiology is tied to the flux density (J / m^2), and the directly absorbed dose (J / kg) can depend both on the stage of plant formation [7] and on their seeding density. Therefore, the task of estimating the loss of harvest of winter grain crops from acute UV radiation as a result of the formation of "ozone holes" over the Arctic requires further, more detailed, research.

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