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UV-B RADIATION EFFECTS ON ELECTRON-TRANSPORT REACTIONS IN BIOMATERIALS

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Abstract. In the present work studied short-term exposure of UV radiation in the B-band on the state of the photosynthetic apparatus in the leaves of two-week-old seedlings of Vicia faba beans and in the chloroplasts of Pisum sativum peas. The increase in pre-irradiation effects in the subsequent dark period indicates the accumulation of active products, which then gradually modify the electron-transport reactions. Experiments show that reactive oxygen species may be such products. The accumulation of reactive oxygen species leads to the gradual destruction of RBF - carboxylase, and then other components of the membrane apparatus of photosynthesis.

Keywords: *UV radiation, photosynthesis, chloroplasts, leaves, EPR signals.*

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1. Introduction

The radiation of the ultraviolet B-band (290-320 nm) is one of the environmental factors that have attracted the attention of researchers in recent years, in particular, in connection with anthropogenic violations of the ozone layer. The influence of UV was considered both independently and in connection with other environmental factors, such as the intensity of photosynthetically active radiation, the presence of herbicides, mutagens, temperature conditions, etc. (Khomutov *et.al.*, 2014; Khalilov *et.al.*, 1993; Nasibova, 2019; White *et.al.*, 2002; Martinez, 2007; Nasibova *et. al.*, 2016; Xiong & Day, 2001). The vast majority of works devoted to this issue consider the long-term effect (days and hours) of UV radiation on an intact plant organism, which manifests itself in changes in physiological functions (total photosynthesis, respiration and photorespiration), the activity of some enzymes. For example, RBF-carboxylase oxygenase, dark carbon exchange, individual stages of electron transport in chloroplasts, as well as changes in the biochemical composition of a number of plant cell components – pigments, proteins, lipids (Kataria *et.al.*, 2014; Khalilov *et.al.*, 2015; Zuk-Golaszewska *et.al.*, 2003). Less attention was paid to the direct effects of UV, effects that develop during short-term exposure and which can hardly lead to any noticeable direct destruction of biological material. The molecular mechanism of such short-term effects remains unclear.

2. Experimental

In this work, we studied short-term exposure of UV radiation in the B-band on the state of the photosynthetic apparatus in the leaves of two-week-old seedlings of *Vicia faba* beans and in the chloroplasts of *Pisum sativum* peas isolated according to (Goldfield *et.al.*, 1979; Khalilov & Nasibova, 2008).

UV radiation sources were PRK-2 high-pressure mercury lamp (irradiation intensity through the UFS-2 filter on the sample surface 20 Vt/m^2) and an excimer pulsed laser (308 nm, pulse energy 0.12 C for a duration of 50 ns and a repetition rate 1 Hz). The irradiated samples were kept in the dark at 4 °C and the EPR spectra were measured after a time interval of 1 min to 5 h after the end of irradiation. EPR spectra were recorded at room temperature on the spectrometer Varian E-4. Kinetic measurements were performed by establishing a magnetic field at a point corresponding to the low-field maximum of the EPR signal 1 of the $P700^+$ centers of photosystems 1 (PS1).

2. Results and discussion

Figure 1 shows typical kinetics of redox transformations of $P700^+$ centers induced by light of various spectral composition in control leaves after UV irradiation and in leaves treated with methylviologen by vacuum infiltration. Light of 707 nm, which primarily excites PS1, induces the oxidation of the P700 pigment, and intense white light causes a nonmonotonic effect (A-B-C), which is determined by the ratio of the rates of electron-transport reactions on the donor and acceptor sides of PS1

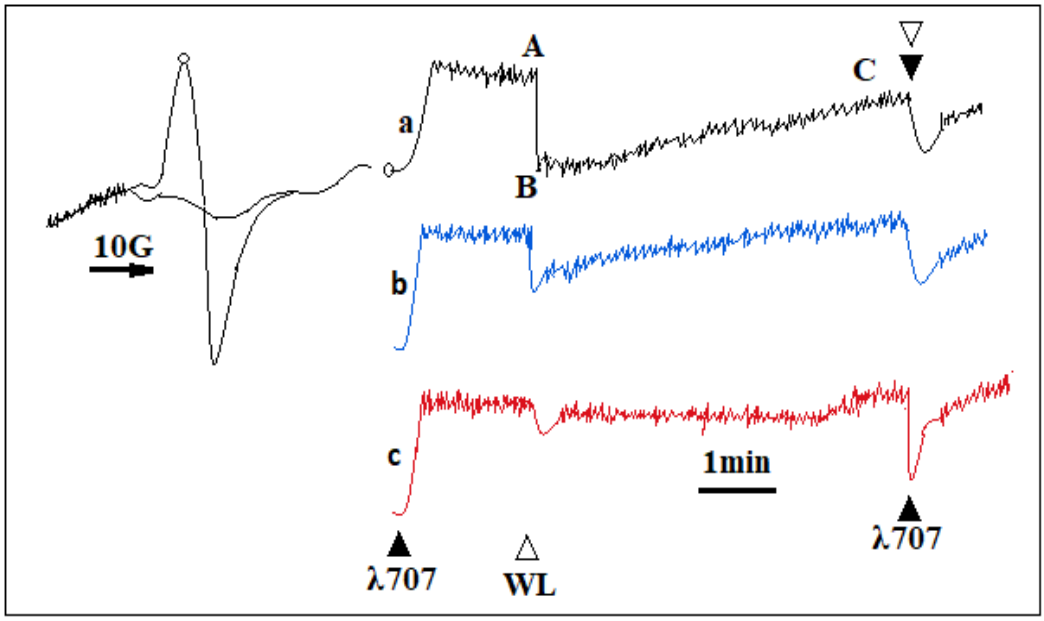

Fig. 1. The EPR signal of V.faba leaves and the kinetics of its photoinduced changes. a) control, without UV exposure; b) The leaf was exposed to continuous UV rays for 20 minutes (kinetics were recorded 30 minutes after the end of irradiation); c) without UV irradiation after kyfiltration with methylviologen. Triangles point up and down, respectively, turning on and off white light (WL, 400 Vt·m^{-2})

According to (Beardall *et.al.*, 2011; Khalilov & Nasibova, 2010; Nasibova *et.al.*, 2017; Khalilov *et. al.*, 2018), the nonmonotonic kinetic effect is due to photoactivation of reactions on the acceptor side of PS1, while the electron transport rate between two photosystems does not change.

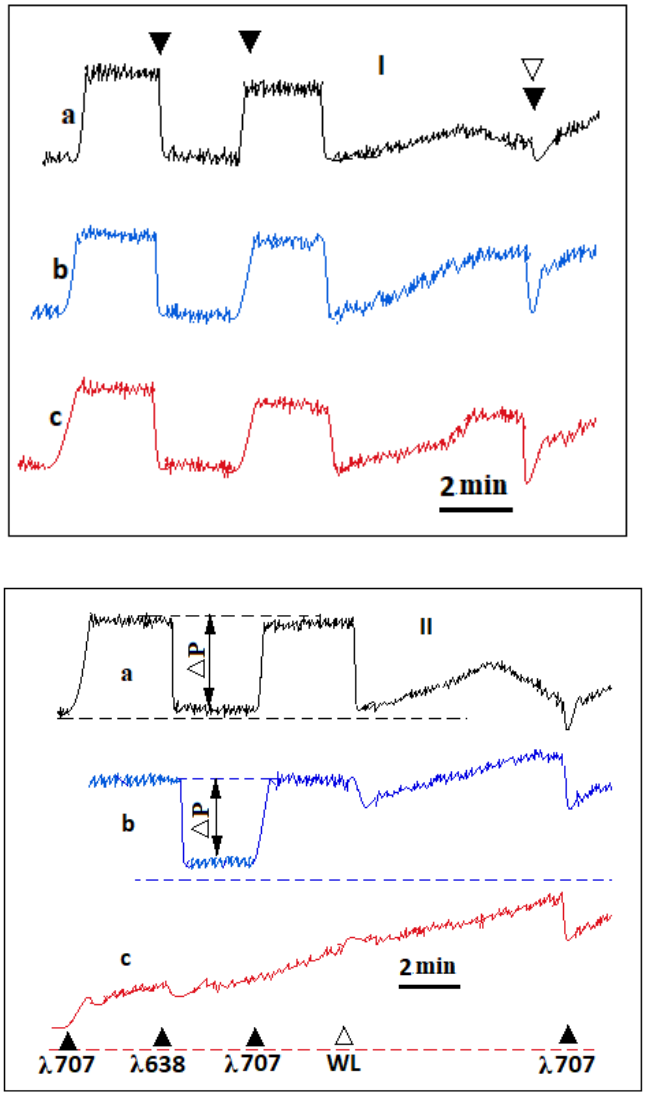

Fig. 2. Kinetics of photo-induced changes of leaf's EPR signal. a) control without UV irradiation; b) UV irradiation on a dark background; c) UV irradiation on a background of white light. I – registration of kinetics after 30 minutes of UV irradiation; II – registration of kinetics after 4 hours of UV irradiation

UV irradiation (up to 20 min) changed the form of the nonmonotonic kinetic effect, moreover reaching the stationary level corresponding to a given intensity of white light accelerated (Fig. 1b). This is apparently not related to the inactivation of non-cyclic transport, since the response to the inclusion of 650 nm light exciting both photosystems did not change under UV irradiation of this dose. It can be assumed that UV-induced acceleration of the growth of the EPR signal after the inclusion of white light is due to the activation of reactions on the acceptor side of PS1. A similar effect is obtained by

treatment with methylviologen, which, as is known, is a mediator of electron trans fer from PS1 to molecular oxygen (Fig. 1c). The reason for the activation of electron outflow reactions from PS1 in UV-irradiated leaves may be an acceleration of the Mehler reaction or a shift in the activity of RDF carboxylase along the oxygenase pathway.

Figure 2 shows the kinetic curves of the same type in the control and irradiated with a UV laser (with a dark background and in the presence of simultaneously acting visible light) leaves. The result obtained by the EPR method correlates with the result of experiments by the MS method (Kavetskyy *et al.*, 2018; Kavetskyy *et al.*, 2020; Nasibova *et al.*, 2013). From figure 2, I, it follows that after UV irradiation against a background of white light, the chromatic transition [707 nm → white light] is modified in such a way that this also indicates an acceleration of the outflow of electrons from PS1.

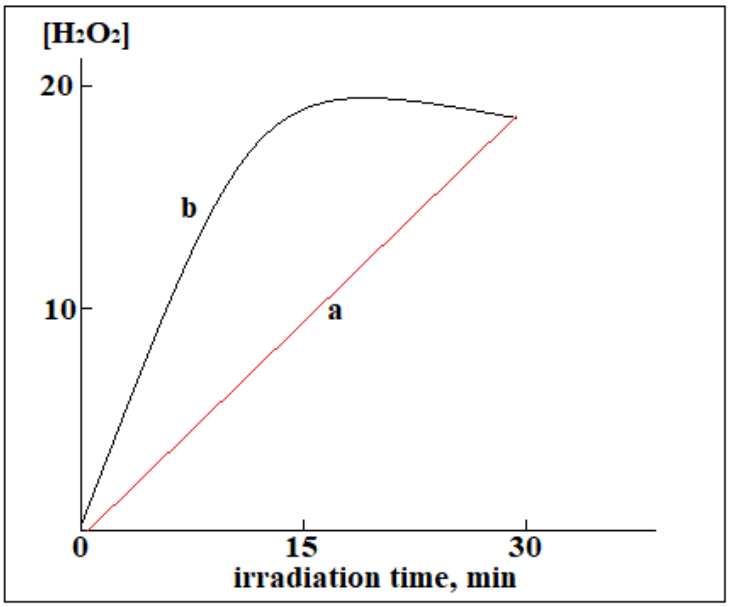

Fig.3. Dependence of the concentration H_2O_2 in a suspension of chloroplasts on the duration of UV irradiation. The intensity of UV radiation on the sample is 28 W · m^{-2}. a) UV irradiation on a dark background; b) UV irradiation on a background of WL.

The increase in pre-irradiation effects in the subsequent dark period indicates the accumulation of active products, which then gradually modify the electron-transport reactions. Experiments on the determination of H_2O_2 in a suspension of UV-irradiated chloroplasts show that reactive oxygen species may be such products. It can be seen from Fig. 3 that with an increase in the radiation dose and in the presence of a white light background, the amount of H_2O_2 increases. The accumulation of reactive oxygen species leads to the gradual destruction of RBF - carboxylase, and then other components of the membrane apparatus of photosynthesis.

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