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ARTICLE

Effects of UV-B radiation and water stress on chlorophyll fluorescence parameters and activity of xanthophyll cycle in leaves of sessile oak (*Quercus petraea*) seedlings

Erzsébet Szőllősi[1], Szilvia Veres[1,2], Péter Kanalas[1], Viktor Oláh[1], Ádám Solti[3], Éva Sárvári[3], Ilona Mészáros[1]*

[1]Department of Botany, Faculty of Sciences and Technology, Debrecen University, Debrecen, Hungary, [2]Department of Agricultural Botany and Crop Physiology, Institute of Plant Sciences, Faculty of Agriculture, Debrecen University Debrecen, Hungary, [3]Department of Physiology and Molecular Plant Biology, Faculty of Sciences, Eötvös Loránd University, Budapest, Hungary

ABSTRACT In the present study we investigated the photosynthetic responses of sessile oak seedlings to UV-B radiation and water stress in growth chamber experiment. Seedlings of sessile oak showed sensitivity to enhanced UV-B radiation which appeared in decreases of maximum photochemical efficiency (Fv/Fm) and actual photochemical efficiency of PSII (ΔF/Fm'). UV-B radiation and water stress induced 150 and 170 % increase of non-photochemical fluorescence quenching (NPQ) and threefold and fourfold elevation of activity of xanthophyll cycle as compared to the control, respectively. Seedlings exposed simultaneously to UV-B and water stress induced larger decrease of Fv/Fm, ΔF/Fm' and RFD than those exposed separately to enhanced UV-B or water withdrawal as compared to control plants. Both UV-B radiation and water stress increased non-photochemical quenching with a parallel enhancement of zeaxanthin formation.
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KEY WORDS

non-photochemical quenching
photochemical efficiency of PSII
sessile oak
UV-B radiation
xanthophyll cycle
water stress

UV-B radiation is an important stress factor for plants which may result in damage to the genetic system and cell membranes, and affect several metabolic processes (Björn 1996; Csintalan et al. 2001; Láposi and Mészáros 2005). The ecological consequences of the increase in UV-B radiation are also important since UV-B-induced alterations in plant physiology and morphology determine the growth and competitive ability of plants, with a resultant impact on the composition of plant communities (Hunt and McNeil 1999). In many habitats water shortage is the main limiting factor of plant productivity which has come into the focus of research as a consequence of global climate change (Tesar et al. 2007). In field, plants exposed to the whole spectrum of solar radiation and often experience photoinhibition and photodamage to the photosynthetic apparatus induced by visible light (Eskling et al. 1997; Láposi et al. 2002; Mészáros et al. 2005) which may be accelerated under stress conditions including the enhanced UV-B radiation and limited water availability. In this work we studied the separate and interactive effects of enhanced UV-B radiation and water stress on photosynthetic activity of seedlings of *Quercus petraea*.

Materials and Methods

One year old seedlings were grown from seeds in phytotronic chamber supplied with white light of 300 μmol m^{-2} s^{-1} in 14/10 hours light/dark periods, temperature of 20/18°C. Supplementary UV-B radiation of 150 μW cm^{-2} was supplied by fluorescence tubes (UV-B 313, Q-Panel, Cleveland, OH) for 8 hours centred into the middle of the 14 hour light period. The tubes were wrapped with 0.1mm cellulose acetate film (Courtaulds, Chemicals, Derby, UK). The experiments were performed for 6 weeks. One set of seedlings were grown under the chamber light and temperature conditions and were well-watered (control plants), the second set of seedlings were exposed to UV-B radiation (UV-B+), the third set of seedlings was exposed to water stress by withdrawal of water (W-) , and the fourth group was exposed simultaneously to UVB and water stress (UVB+, W-). Chlorophyll florescence parameters (Fv/Fm, ΔF/Fm'), RFD, NPQ) were measured by means of PAM 2000 fluorometer (WALZ, Germany). Xanthopyll cycle pigments were measured 80% acetonic extract by reverse phase HPLC method (JASCO UV/VIS, Japan).

Results and Discussion

UV-B treatment reduced the maximal photochemical efficiency of PSII (Fv/Fm) of dark adapted leaves by 20% as compared to the control seedlings (Fig. 1). Under UV-B the actual photochemical efficiency (ΔF/Fm') of light acclimated leaves exhibited larger (40%) decrease and relative fluorescence

*Corresponding author. E-mail: immeszaros@puma.unideb.hu

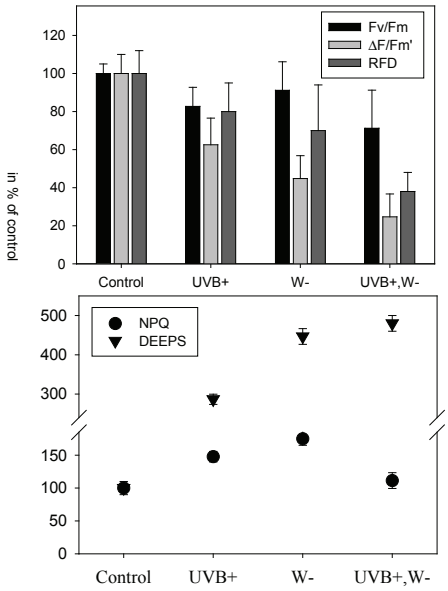

Figure 1. Effect of UV-B radiation and water withdrawal on maximal photochemical efficiency (Fv/Fm) of pre-darkened leaves and actual photochemical efficiency (ΔF/Fm'), relative fluorescence decrease (RFD), non-photochemical chlorophyll quenching and de-epoxidation state (DEEPS) of xanthophyll cycle in light acclimated leaves of sessile oak seedlings.

decrease (RFD) reached also lower values (by 20 %) than in control plants. As compared to UV-B exposure, decrease of ΔF/Fm' and RFD became more severe when seedlings were subjected to water stress. Fv/Fm was influenced similarly under water withdrawal as under UV-B exposure. Simultaneous UV-B exposure and water stress resulted in further reduction in all fluorescence parameters, but those measured in light acclimated leaves were reduced at larger extent. Both UV-B radiation and water stress induced 150-170 % increase of non-photochemical fluorescence quenching (NPQ). Relative proportion of de-epoxi-xanthophylls (zeaxanthin and antheraxanthin) formed from violaxanthin to the total violaxanthin cycle (VAZ) pool expressed as DEEPS has been reported to reflect the down-regulation of PSII and partly the appearance of non-photochemical quenching (Demmig-Adams and Adams 2000). Although de-epoxi-xanthophylls have been reported to play direct role in non-photochemical fluorescence quenching (Gilmore 1997), DEEPS index indicated much larger (300-450%) increases in activity of xanthophyll cycle in sessile oak seedlings exposed to UV-B radiation and water stress which suggest that de-epoxi compounds of VAZ cycle pool may be involved in other protective processes (Figure 1). Simultaneous application of UV-B and water withdrawal resulted in smaller increase of NPQ than separate exposure of seedlings to UV-B radiation or water stress. DEEPS index reached the highest value when plants were exposed jointly to UV-B and water stress but it was close to the value experienced under water stress. Under enhanced UV-B and water stress DEEPS changed in positive correlation with NPQ.

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