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Effects of supplemental UV-B radiation on photosynthesis performance and UV-B absorbing compounds in leaves of two oak species

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ABSTRACT The aim of this work was to compare the photosynthetic responses of two tree species (*Quercus petraea*, *Quercus robur*) and to determine the leaf level protection under enhanced UV-B radiation in outdoor experiments. Three year old seedlings of both species were exposed to enhanced UV-B radiation (supplementing the ambient level with 40%) from bud break until leaf senescence. Under enhanced UV-B, increases of specific leaf mass (SLM) and reduction of leaf chlorophyll content per dry weight basis were observed but the total carotenoid content remained high. Both oak species responded with an increase of VAZ pool to enhanced UV-B. High values of potential photochemical efficiency of PS2 (Fv/Fm) were observed in both species during the growing season. On clear sunny days loss of Fv/Fm was observed from morning till midday which was larger under enhanced UV-B for both species suggesting that UV-B exposure enhanced the sensitivity of seedlings to photoinhibition. The enhanced UV-B induced increases in the amount of UV-B absorbing compounds in leaves of *Q. robur* but it slightly affected these traits of leaves of *Q. petraea*.
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KEY WORDS

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flavonoids

Decrease in stratospheric ozone level are predicted to result in an increase in UV-B radiation reaching the Earth surface within the next few decades Although the effects might be the most dramatic in the Antarctic, there are also significant signs of increasing UVB radiation level in the temperate regions too (Caldwell et al. 1995). Numerous studies have been performed to study the effects of enhanced UV-B radiation on plants. It is now highly accepted that there is a great variation in sensitivity to UV-B radiation among the species which highly depends on other environmental factors, mainly on level of irradiance (Bornman 1989). Several plant species can avoid efficiently the physiological damages induced by UV-B radiation through the constitutive appearance or a rapid development of effective protective mechanisms. In the present study we investigated the responses of photosynthetic activity of seedlings of two oak species *(Quercus petraea* and *Quercus robur)* to visible light and elevated UV-B radiation in outdoor UV-B supplementation experiments. There are clear differences in the habitats of these species in Hungary, while *Quercus robur* occur in lowlands of the country, *Q. petraea* prefers the hilly and mountainous regions. Both species represent important sylvicultural and economic value in Hungary.

Materials and Methods

Apparently uniform, three year old seedlings of *Quercus petraea*, *Quercus robur,* were purchased from a nursery garden and planted into slightly acidic soil (mixture of brown forest soil and commercial flower soil, 50:50) and were placed in 1.5 x 1.5 cm experimental plots. In 4 plots plants were exposed to supplemental UV-B radiation of 80 μW cm^{-2} (approx. 40% of the summer maximum of the ambient UV-B radiation) provided by fluorescence tubes (UV-B 313, Q-Panel, Cleveland, OH) which were wrapped with 0.1mm cellulose acetate filter (Courtaulds, Chemicals, Derby, UK) to eliminate the UV-C radiation (Mészáros et al. 2001). In control plots (4 plots) plants received only natural radiation. A part of seedlings were also placed under shade of canopy of adjacent trees. The outdoor UV-B experiments were running from starting the leaf development until the leaf senescence from the middle of May until the end of September. There were no differences in the water supply of seedlings in both plots.

Chlorophyll fluorescence was measured by means of PAM 2000 fluorometer (WALZ, Germany). Chlorophyll fluorescence of Fv/Fm was used to describe the potencial photochemical efficiency of PS2 (Schreiber et al. 1994) and it was determined in intact plants after a 20 min dark adaptation period. Photosynthetic pigment composition of leaves was measured in 80% acetone extract. Chlorophylls and total carotenoids were determined by spectrophotometric method (Shimadzu UV/VIS spectrophotometer) using the equations of Wellburn (1994). Carotenoid composition was studied by

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reversed phase HPLC method, (UV/VIS HPLC, Jasco, Japan). UV-B absorbing compounds were measured spectrophotometrically after extraction by mixture of methanol:HCl:H_2O (90:1:1; Day 1993).

Results and Discussion

Leaves of UV-B treated seedlings of both oak species maintained a relatively high value of potential photochemical effieciency (Fv/Fm) during the vegetation season which often exceeded that of the control plants. The results suggest that these two species can be described by photosynthetic insensitivity to UV-B under the experimental conditions. It can also be concluded that under conditions of outdoor supplementation UV-B radiation induced damages to the PSII centre do not occur. There occurred slight daily fluctuations in Fv/Fm. Control seedlings of both species lost a 8-10% of the potential photochemical efficiency from morning till midday. Under enhanced UV-B radiation the midday loss of Fv/Fm is slightly increased, but the differences from control values were not statistically significant. It suggests that UV-B exposure increase the sensitivity of seedlings to photoinhibition.

The actual photochemical activity was measured after illumination of attached leaves with two different actinic light intensities (150 and 900 μmol m^{-2} s^{-1}). With no UV-B the ΔF/Fm' values of oak species ranged between 0.40-0.50 measured after 5 min acclimation to low actinic light. There were significant interspecific differences of actual photochemical efficiencies. At low actinic light *Quercus robur* showed higher actual photochemical efficiency than *Quecus petraea.* After acclimation to high actinic light ΔF/Fm' values decreased, and ranged between 0.08 and 0.11. UV-B supplementation did not cause a significant decrease of ΔF/Fm'. Like the actual photochemical activity, the non-photochemical fluorescence quenching showed also interspecific variations and changes with the applied actinic light intensity. There were generally higher NPQ values for *Quercus robur* than for *Q. petraea.*

Leaves of both species showed smaller chlorophyll content under elevated UV-B radiation as compared to the control plants. Under UV-B supplementation the total carotenoid content expressed to dry weight or leaf remained nearly at the control level and did not show so large changes as the total chlorophyll content. Both oak species can be described by relatively large VAZ pool. Among the two species *Quercus petraea* can be generally characterized with the larger VAZ pool. Both oak species responded with an increase of VAZ pool to the enhanced UVB. The degree of deepoxidation of VAZ (DEEP) was smaller for *Quercus robur* than *for Quercus petraea*. UV-B supplementation decreased the conversion of violaxanthin into zeaxanthin and antheraxanthin.

As a costitutive character of leaf chemistry and physiology both oak species accumulate in relatively high concentration not only at sun light but at low light conditions too. The slight inhibition in photosynthetic processes experienced in leaves of oak species under outdoor UV-B supplementation conditions can be attributed to the absorbing capacity in upper layer of the epidermis. The supplementary UV-B caused increases in the concentration of UV-B absorbing compounds (flavonoids) in leaves of *Quercus robur*, but did not have significant effect in case of *Quercus petraea*. Both species responded very sensitively with changes in SLW to the growth light condtions. The control plants of species grown at full sun light show relatively thick and dense leaves. The elevated UVB radiation resulted in the incraese of SLW of each species which took place in correlation with the accumulation of flavonoids in case of *Quercus robur*.

In summary this study provide evidence that leaves of both oak species may be adequatly protected from the inhibition of photosynthesis potencially induced by elevated levels of solar UV-B radiation. The results suggest that acclimation of tree species to high intensity and daily fluctuations of visible light can also serve the acclimation to the enhancement of UV-B radiation.

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