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BRIEF COMMUNICATION

# Responses of pea and triticale photosynthesis and growth to long-wave UV-B radiation

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## Abstract

Pea plants were more susceptible to long-wave UV-B irradiation (305 - 320 nm, 7.7 kJ $m^{-2}$ $d^{-1}$, 4 weeks) in comparison with the triticale. This difference was more apparent from the changes in total area of leaves and dry mass of shoots, rather than from the parameters of chlorophyll fluorescence and net photosynthetic rate.

*Additional key words*: chlorophyll fluorescence, $CO_2$ assimilation rate, net photosynthetic rate, *Pisum sativum*, *Triticosecale*.

UV-B radiation (280 - 320 nm) can change the anatomical features of plants, inhibit photosynthesis, slow down their growth, reduce biomass, and lower the crop yield (*e.g.* Caldwell 1977, Teramura and Sullivan 1994). Plants developed different defensive mechanisms, of which the most important is the increased production of flavonoids in the epidermis, absorbing the ultraviolet radiation (Robberecht and Caldwell 1978, Tevini *et al.* 1991, Teramura and Sullivan 1994). The aim of this paper was to characterize some physiological reactions of pea and triticale plants to enhanced long-wave UV-B radiation.

Seeds of pea (*Pisum sativum* L.) cv. Sześciotygodniowy and triticale (× *Triticosecale* Wittmack) cv. Moreno were sown in September 1997 into pots with soil (500 $cm^3$). The pots were placed in a greenhouse [temperature 22 °C, irradiance of PAR 1000 μmol $m^{-2}$ $s^{-1}$ at noon], as described earlier (Skórska *et al.* 1997). The plants were watered daily, and fertilised twice a week with 50 % Hoagland nutrient solution ($KNO_3$ - 304 mg $dm^{-3}$, $MgSO_4 . 7\ H_2O$ - 124 mg $dm^{-3}$, $NH_4H_2PO_4$ - 12 mg $dm^{-3}$, $Ca(NO_3)_2 . 4\ H_2O$ - 471 mg $dm^{-3}$, 0.001 % iron citrate, microelements). One part of three-week old plants, in the stage of the second leaf, was treated with UV-B irradiation using two lamps *TL100W/01* (*Philips*, Eidhoven, The Netherlands) for 4 h per day, from 10:00 to 14:00. The maximum emission was at 311 nm (Fig. 1). The irradiance was 1.0 W $m^{-2}$, which corresponded to the daily biological effective dose of UV-B ($UV\text{-}B_{BE}$) 7.7 kJ $m^{-2}$ $d^{-1}$, calculated using the generalised plant action spectrum to UV-B (Caldwell 1977) and normalised to unity at 300 nm. Control plants were placed in the same conditions and separated from the UV-B radiation by a glass-filter absorbing most radiation at wavelength below 320 nm; the irradiance was 0.10 W $m^{-2}$ ($UV\text{-}B_{BE}$ 0.77 kJ $m^{-2}$ $d^{-1}$). This glass filter did not absorb little quantities of blue radiation, emitted by the lamp *TL100W/01*. The UV-B irradiance was measured by means of a radiometer *IL1400* with a detector *SEL240-UVB1* (*International Light Co.*, Newburyport, USA).

The chlorophyll *a* fluorescence induction was measured on intact leaves using a *Plant Efficiency Analyser PEA* (*Hansatech Instruments*, Kingslynn, England). The leaves were dark-adapted using special clips belonging to the equipment of *PEA* analyser. Red light (1200 μmol $m^{-2}$ $s^{-1}$) was used for excitation. $F_0$, $F_m$, $F_v$ represent initial, maximum, and variable fluorescence ($F_v = F_m - F_0$), and $t_m$ is the time to reaching maximal fluorescence. The net photosynthetic rate (μmol($CO_2$) $m^{-2}$ $s^{-1}$), and transpiration rate (mmol($H_2O$) $m^{-2}$ $s^{-1}$) was measured

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*Abbreviations*: E - transpiration rate; $F_0$, $F_m$, $F_v$ - initial, maximum, and variable fluorescence ($F_v = F_m - F_0$); $P_N$ - net photosynthetic rate; $t_m$ - time to reaching maximal fluorescence.

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by *LCA-4* gas-exchange system (*ADC*, Hoddesdon, England) with a portable leaf chamber *PLC4*. The content of pigments absorbing UV (flavonoids) was quantified on

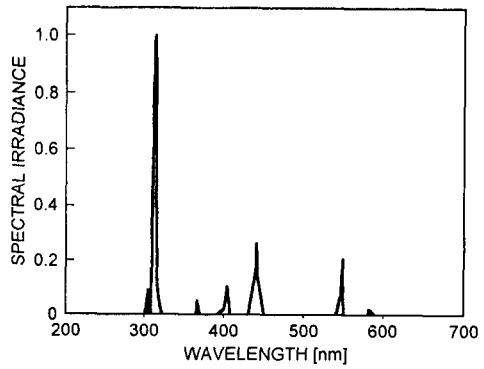


Fig. 1. Emission spectrum of the lamp *Philips TL 100/01* used in the experiment, normalised to the maximum (311 nm).

the basis of UV absorption spectra of leaves extracts, obtained after placing 2.5 $cm^2$ of leaves tissue in 5 $cm^3$ of the solution etanol:water:acetic acid (79:20:1), and heating for 30 min at 60 °C. As the index of flavonoids concentration, the absorbance at 305 nm of 1 g of leaf dry mass ($A_{305}$ $g^{-1}$) was adapted, according to Caldwell *et al.* (1994). The specific leaf mass (SLM), or the relative leaf thickness, was determined as the ratio of the leaf dry mass to leaf area. The area of each leaf was measured by means of *Delta-T Image Analysis System* (*DIAS*, Burwell, England). The mass of roots and shoots of the plants were weighed after drying at 105 °C to constant mass, using a precision scale (*WPS 36*, *Radwag*, Radom, Poland). Results were statistically treated by analysis of variances.

The decrease in $F_v/F_m$ and $F_v/F_0$ in pea plants (Table 1) indicated the reduction in the capacity of the primary photosynthetic reactions in photosystem II (Krause *et al.* 1990). The relatively little changes in $F_v/F_m$ indicated a slight photoinhibition caused by the UV-B radiation applied. $F_v/F_0$ was reduced by *ca.* 10 %, which indicated slight disturbances in the functioning of the complex of water decomposition, localised in the donor part of the photosystem II. These parameters did not change in triticale, similarly as $t_m$ in both species studied.

Table 1. Characteristics of pea and triticale plants grown for 4 weeks in the greenhouse in absence (control) or presence (UV-B) of UV-B radiation (305 - 320 nm, $UV\text{-}B_{BE}$ = 7.7 kJ $m^{-2}$ $d^{-1}$). Means from 6 - 8 replications, the asterisks denote the significant values at $P < 0.05$.

| Characteristics | Pea control | UV-B | Triticale control | UV-B |
|---|---|---|---|---|
| Total area of leaves [$cm^2$ $plant^{-1}$] | 106 ± 17 | 69 ± 11* | 55 ± 13 | 53 ± 14 |
| Dry mass of shoot [mg $plant^{-1}$] | 338 ± 65 | 220 ± 48* | 200 ± 18 | 199 ± 17 |
| Dry mass of roots [mg $plant^{-1}$] | 107 ± 6 | 88 ± 5* | 100 ± 8 | 51 ± 6* |
| Leaf area/mass ratio [g $m^{-2}$] | 9.0 ± 0.8 | 7.5 ± 0.1* | 14.1 ± 0.1 | 14.1 ± 0.1 |
| $P_N$ [μmol($CO_2$) $m^{-2}$ $s^{-1}$] | 5.6 ± 0.8 | 5.1 ± 0.9 | 4.5 ± 1.2 | 3.8 ± 0.9 |
| E [mmol($H_2O$) $m^{-2}$ $s^{-1}$] | 1.23 ± 0.17 | 0.92 ± 0.19* | 0.89 ± 0.29 | 0.43 ± 0.22* |
| $F_v/F_m$ | 0.836 ± 0.005 | 0.824 ± 0.007* | 0.824 ± 0.007 | 0.826 ± 0.008 |
| $F_v/F_0$ | 5.10 ± 0.23 | 4.71 ± 0.25* | 4.5 ± 1.2 | 3.8 ± 0.9 |
| $t_m$ [ms] | 342 ± 35 | 351 ± 43 | 328 ± 87 | 314 ± 54 |
| Flavonoids [$A_{305}$ $g^{-1}$(DM)] | 420 ± 91 | 476 ± 72 | 223 ± 8 | 248 ± 28 |

The net photosynthetic rate ($P_N$) did not change in irradiated plants of both species, but the transpiration rate (E) was reduced by 25 % for pea, and 50 % for triticale (Table 1). The leaves of pea plants did not produce significantly more flavonoids under UV-B radiation. As far as triticale is concerned, the content of flavonoids did not change after 4 weeks of UV-B irradiation, but after two weeks of UV-B irradiation, the content of flavonoids increased by 21 % in comparison with the control plants (data not shown).

The UV-B irradiation used caused a slight decrease in the above parameters in studied plants. This can be explained on account of the fact that *TL100/01* lamps emit UV-B in narrow range of 305 - 320 nm which is not as damaging as radiation below 300 nm (El Ghorr and Norval 1997). Considerably stronger decrease in photosynthesis was shown in plants after short-term irradiation of UV-B in the entire range of 280 - 320 nm (Tevini and Pfister 1985, Skórska 1996). However, the total area of pea leaves was reduced by 35 % in response to UV-B radiation, the specific leaf mass by 17 %, and dry mass of shoot by 35 %; these features did not change in triticale. Cen and Bornman (1993) showed that the leaf area and leaf dry mass of rape plants grown under similar dose of UV-B radiation was decreased compared with the control plants. It is interesting that dry mass of roots was reduced by 17 % for pea, and by almost 50 % for triticale.

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