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The effect of UV-B radiation on the chlorophyll fluorescence parameters of the husked and the naked oat

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Summary

Naked oat variety of STH296 showed higher tolerance than traditional variety Bajka on short-term UV-B radiation ($UV\text{-}B_{BE}$=11 $kJ \cdot m^{-2}$) on the stage of primary photosynthesis reaction recorded using chlorophyll fluorescence induction of the leaves.

Key words: *Avena sativa*, chlorophyll fluorescence, naked oat, ultraviolet, UV-B

INTRODUCTION

Increasing degradation of the ozonosphere for almost thirty years is a cause of enhanced level of ultraviolet radiation, particularly in the range of UV-B, i.e. 280-320 nm, reached the Earth's surface (Molina and Rowland 1974). UV-B radiation affects the structure of biological membranes, inhibiting photosynthesis, slowing of growth and lowering of crop plants yield (Caldwell 1977). Among different species or even varieties of crop plants rather large differentiation in the susceptibility to UV-B radiation is observed (Caldwell et al. 1998). Results of the studies on cereal indicate on their relative tolerance to UV-B however also between them exist large differences (Beyschlag et al. 1988, He et al. 1993, Skórska 1996, 1999). Still we do not know about susceptibility of oat plants to ultraviolet. Thus, the aim of this study was susceptibility test of photosynthetic apparatus of the oat plants to short-term but relative large dose of UV-B irradiation. Among the studied varieties, there was allowed the traditional variety Bajka and two forms of the naked oat: variety Akt, bred in Poland

and introduced for crop in 1997 and the new variety STH296 (Nita and Orłowska-Job 1996).

MATERIAL AND METHODS

Material for the studies came from the microfield experiment performed on the vegetation hall of Agricultural University of Szczecin. It included three cultivars of oat (*Avena sativa* L.): Bajka (husked), Akt and STH 296 (naked). Grain was sowed on 4th April 1998 widespacing 10×2.5 cm. At the phase of caryopsis water ripe (71 DC in the Zadoks scale), six flag leaves were randomly collected from the distinct plants of the all variety. From each of them two segments (ca. 2.5 cm) were cut, within 5 cm from the leaf apex. One part of these samples - as the control - was placed in the dishes with 50% Hoagland nutrient in the darkness. The second part was subjected to UV-B irradiation (λ_{max} = 312 nm, 8 W·m^{-2}, UV-B$_{BE}$=11 kJ·m^{-2}) for 60 min using the lamp type VL-115 M (Vilber Lourmat, France). Magnitude irradiation dose was the same as in the earlier studies on the susceptibility of crop plant on the UV-B (Skórska 1996). Intensity of UV-B radiation was measured by means of the radiometer IL-1400 with the detector SEL240 UVB-1/W (International Light Inc., USA).

After irradiation, the measurements of chlorophyll fluorescence induction were performed using the PEA fluorometer (Hansatech Instr. Ltd., UK). The curves of chlorophyll fluorescence induction were recorded for 2 min, using excitation of the red light (1200 µmol·m^{-2}·s^{-1} PAR). The following parameters were calculated: F_v/F_m, F_v/F_o, S and Rfd = $(F_m-F_s)/F_s$, where F_o, F_m, F_v, F_s denote respectively intensity of the initial, maximal variable ($F_v=F_m-F_o$) and steady-state fluorescence; parameter S is proportional to the area above the curve of chlorophyll fluorescence induction and associated with the amount of the plastoquinones pool in the photosystem II, Rfd - vitality index (Lichtenthaler et al. 1986).

All measurements were done in 6 replications (separate plants). The results for the respective parameters were elaborated by means of two-way analysis of variance, and the Tukey test was used to separate the groups of means ($p < 0.05$). The means marked with the same letter do not significantly differ.

RESULTS AND DISCUSSION

As a result of UV-B irradiation the decrease of the F_v/F_m meanly by 9%, compared to the control (not irradiated), was observed which indicates the photoinhibition changes in the photosystem II of the leaves (Gorkom 1986). The clearest decrease, by 17%, was in the traditional variety Bajka (Tab. 1). The decrease in this parameter after UV-B irradiation was statistically not significant in the leaves of the naked form STH 296 and Akt. The parameter F_v/F_m showed relative small variability, measured as a variability coefficient cv=7,2%.

Table 1.

The effect of UV-B radiation on chlorophyll fluorescence parameters of oat leaves.

Variety	F_v/F_m		S		F_v/F_o		Rfd	
	Control	UV-B	Control	UV-B	Control	UV-B	Control	UV-B
Bajka	0.60^{b}	0.50^{c}	76.5^{a}	55.1^{b}	1.51^{b}	1.03^{b}	1.04^{ab}	0.56^{c}
Akt	0.63^{b}	0.55^{bc}	66.4^{ab}	51.6^{b}	1.69^{b}	1.26^{b}	1.35^{a}	0.77^{bc}
STH 296	0.76^{a}	0.74^{a}	24.7^{c}	21.8^{c}	3.19^{a}	2.93^{a}	0.90^{b}	0.82^{bc}
Mean	0.66	0.60	55.9	42.8	2.13	1.74	1.10	0.72
Effect significance:								
Variety (o)	**		**		**		*	
UV-B (u)	**		**		**		**	
o × u	(*)		ns		(*)		*	
cv (%)	7.2		23		20		25	

abc – the means denoted by the same letter (for one parameter) do not differ significantly ($p<0.05$)
(*) effect significance at the level $p<0.1$, *$p<0.05$, **$p<0.01$, ***$p<0.001$; ns - not significant

The UV-B radiation caused a decrease in parameter S meanly by 23%, indicating a reduction of the plastoquinones pool in the photosystem II (Govindjee 1995). Similarly as F_v/F_m, variety Bajka showed more susceptibility to the applied UV-B dose - the value of S decreased by 28%.

Parameter F_v/F_o, proportional to activity of the water-spliting complex on the donor side of the photosystem II (Schreiber et al. 1994), was reduced meanly by 18% after UV-B irradiation, in comparison with the control. Reaction of all the three varieties was similar. The variety STH 296 showed the highest value of this parameter, excelling over twice the other varieties.

The clearest reduction of the coefficient Rfd as a result of UV-B irradiation was observed in the variety Bajka (by 46%) and the naked variety Akt (by 43%). The naked variety STH 296 showed more tolerance to the applied UV-B dose, however it characterised lower initial value of this coefficient. According to the interpretation of Lichtentchaler et al. (1986), decrease in Rfd can indicate a disturbance of cooperation between the photochemical reactions and the dark enzymatic process.

To summarise, one could conclude that the new naked oat variety STH296 showed more tolerance to the applied UV-B dose than traditional variety Bajka, and the other naked variety Akt. Among the studied parameters, F_v/F_m was characterised the least variability (cv=7,2%).

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Wpływ promieniowania UV-B na parametry fluorescencji chlorofilu liści owsa oplewionego i nieoplewionego

Streszczenie

Nieoplewiona odmiana owsa STH296 wykazała większą niż tradycyjna oplewiona odmiana Bajka tolerancję na krótkotrwałe promieniowanie UV-B ($UV\text{-}B_{BE}$=11 $kJ \cdot m^{-2}$) na etapie pierwotnych reakcji fotosyntezy rejestrowanych przy wykorzystaniu indukcji fluorescencji chlorofilu liści.