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The Effect of UV-B Radiation and Nutrient Availability on Growth and Photochemical Efficiency of PS II in Common Duckweed

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S u m m a r y

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Common duckweed (*Lemna minor* L.) was grown in the laboratory under artificial ultraviolet-B (UV-B) radiation in media with different concentrations of nutrients. Three different levels of UV-B radiation (15 kJm^{-2}, 19 kJm^{-2} and 26 kJm^{-2} per day) were applied. At the end of the experiment, growth rate, chlorophyll content and photochemical efficiency of photosystem II were determined in UV-B treated and in control plants. The data indicate that the highest level of UV-B radiation significantly influences the growth rate of treated plants. Total chlorophyll content in irradiated plants was also lower, but photochemical efficiency of PS II was not affected. Under medium level of UV-B radiation the effect on growth was observed only when the experimental plants were not nutrient limited.

I n t r o d u c t i o n

The increase in ultraviolet (UV)-B radiation on the Earth's surface due to the thinning of the ozone layer, influences the growth and the development of plants (TEVINI & TERAMURA 1989, ROZEMA & al. 1995). Numerous studies have been conducted in order to estimate the influence of UV-B radiation on growth and development of different plant species (SULLIVAN & TERAMURA 1992, TEVINI 1994). In many cases the decrease of growth rate is due to the disturbances in photosynthetic processes (BORNMAN 1989, TERAMURA & SULLIVAN 1994).

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Photoinhibition caused by UV-B radiation may also additionally decrease net photosynthesis (TEVINI 1994).

This paper presents the results of the study of the influence of UV-B radiation on vegetative reproduction and photochemical efficiency of photosystem II in the quickly growing aquatic plant common duckweed (*Lemna minor* L.). Previous investigations on the influence of UV-B radiation on different processes in primary producers in aquatic ecosystems were directed mainly to algae. Aquatic vascular plants have been neglected, even though some of them are exposed to direct solar radiation, due to their floating growth form.

Material and Methods

Plant material and growth conditions

Common duckweed is a widespread aquatic species. It has reduced leaves, but short, flattened stems give an impression of the leaves. *L. minor* is a quickly growing plant, which doubles its biomass every 1.4 to 1.8 days (WANG 1991). As a floating plant it is directly exposed to solar radiation and thus it could be more sensitive than other species.

Plants were cultured in the growth chamber under controlled conditions (temperature 23+3°C, relative humidity 100%), similar to those proposed by ASTM 1992 for *Lemna gibba*. The culture was maintained in Jaworski's medium (BGM - 5 times more concentrated than for algae) (THOMPSON & al.1988).

In a sequence of the experiments different levels of UV-B radiation and different concentrations of nutrients in the medium were applied. The amount of nutrients was regulated by dilution of medium. Irradiated and control plants were grown in pure distilled water, Jaworski medium and 5 times concentrated Jaworski medium. In each experiment five parallel samples were exposed to UV-B radiation and the same number for the control. Twelve fronds were taken for each parallel sample. The photosynthetically active radiation (PAR, 400 -700 nm) was 150 µmol $m^{-2} s^{-1}$. The source of light was 300W Osram Ultra -Vitalux bulbs which has a spectrum similar to that of the sunlight in mountainous areas (Technical documentation, OSRAM). The quantity of UV-B radiation was monitored with a UV-B sensor (peak sensitivity 313±2 nm, bandwidth - full width at half maximum 26±1 nm, Delta T Devices). Over 12-hour period 15 kJm^{-2} (level I), 19 kJm^{-2} (level II) and 26 kJm^{-2} (level III) of UV-B radiation were applied. The amounts seems to be rather high, but the specific properties of the sensor should be taken into account. The levels of UV-B radiation used in the experiment are comparable with the range of those used in different studies reviewed by CALDWELL & FLINT 1994. Each experiment lasted 168 hours. At the end of the experiment growth analysis was performed and chlorophyll fluorescence kinetics was monitored.

Growth rate estimation

After termination of each experiment the growth rate was estimated as total number of fronds, number of green fronds and fresh, as well as dry weights.

Chlorophyll content

The chlorophyll a content in the plantlets was determined according to GOLTERMAN & al. 1978.

Chlorophyll fluorescence measurements

Chlorophyll fluorescence was measured in vivo with a PSM fluorometer (Plant Stress Meter, Biomonitor, Sweden). Before measurements plants were kept for 20 minutes in dark. Fast (5 seconds) fluorescence kinetic was monitored. The quantum yield of photosystem II (PS II) was estimated by the F_v/F_m ratio, where F_m stands for peak or maximum fluorescence and F_V is variable fluorescence (peak level minus initial level, F_m - F_o) (ÖQUIST & WASS 1988).

Statistical analyses

All measurements were carried out on five parallel samples. The significance of the differences according to the control in measured parameters was tested with one-way Student's t-test.

Results and Discussion

The relative response of *Lemna minor* to UV-B radiation and nutrient concentration is presented in Table 1. UV-B radiation exerted influence on growth rate and photochemical efficiency of plants to different extent, depending on the treatment in the experiment. In plants treated with 15 kJm^{-2} no effect on growth parameters was observed. The total number of fronds, number of green fronds, total fresh weight and total dry weight showed no differences in comparison to the control, but total chlorophyll a content was significantly affected. Measurements of the chlorophyll fluorescence showed slight differences.

When 19 kJm^{-2} of UV-B radiation was applied the effect on all measured parameters, with exception of the F_v/F_m ratio, was significant in nutrient rich medium.

In experimental plants treated with 26 kJm^{-2} of UV-B radiation, growth parameters showed significantly lower values than in the control group without any respect to the nutrient level. The effect of nutrient shortage can be observed when comparing dry weights per frond. Comparison of dry weights per frond in experiments with different nutrient levels showed that the fronds grown in distilled water weighed approximately half of the mass of the fronds cultured in the nutrient rich medium (in average 43 and 99 µg DW, respectively). Total chlorophyll a was affected without any respect to the nutrients in the medium. The differences in total chlorophyll are mainly due to senescence processes.

The scientific review (ROZEMA & al. 1995) revealed a large interspecific variation in responses to UV-B radiation. In plants with long-lived foliage the injuries appeared after long term treatments only. In common duckweed visible injuries occurred already in few days. In many cases the parental fronds became pale green and some of them died off after one-week treatment.

Increased sensitivity in an early phase of growth is mainly due to incomplete development of epidermis and cuticula (DELUCIA & al. 1992). Accumulation of secondary compounds in the epidermis can alter the optical properties of the leaves and retain a great deal of UV-B radiation (BORNMAN & VOGELMAN 1991, TERAMURA & SULLIVAN 1994). Common duckweed grows continuously. It has poorly developed epidermis and cuticula. For that reason newly grown fronds are very vulnerable. Further investigations are needed in order to estimate the role of the epidermis in protection of underlying tissue. On the basis of the present results we can conclude that enhanced UV-B radiation significantly reduced vegetative reproduction in common duckweed (Table 1).

Table 1. Relative decrease (% of control) of different parameters in common duckweed in relation of different levels of UV-B radiation (level I - 15 kJm^{-2}, level II - 19 kJm^{-2} and level III - 26 kJm^{-2} per day) and different nutrient levels (n=5, - no significance, * $P \leq 0.05$, ** $P \leq 0.01$).

Level		I			II			III	
Parameter	dist. water	medium	medium 5xconc.	dist. water	medium	medium 5xconc.	dist. water	medium	medium 5xconc.
Total no. of fronds	2.27	-6.64	10.35	8.67	2.63	21.46	31.79	16.96	30.1
	-	-	-	-	-	**	**	**	**
No. of green fronds	7.78	-5.02	9.74	10.81	7.02	22.56	41.45	22.02	33.0
	-	-	-	-	-	**	**	**	**
Fresh weight	-0.04	12.84	11.1	34.02	12.83	37.08	50.37	32.04	44.4
	-	-	-	**	-	**	**	**	**
Dry weight	5.70	13.36	1.66	20.73	11.60	37.64	48.06	28.54	37.7
	-	-	-	-	-	**	**	**	**
Total chlorophyll a	6.72	13.01	42.93	9.68	5.11	38.20	24.28	25.69	47.1
	-	-	**	-	-	**	*	**	**
Fv/Fm ratio	1.51	2.5	7.25	5.56	2.5	3.85	-4.17	-1.37	2.6
	-	*	*	*	-	-	*	-	-
Chlorophyll/ frond	-13.8	16.5	36.4	-4.0	-1.8	18.9	-32.9	4.9	20.0
	-	**	**	-	-	*	**	-	**
Dry weight/ frond	5.1	17.5	-10.2	13.9	0.6	21.2	24.0	14.7	10.1
	-	**	-	-	-	**	*	-	-

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