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IMPACT OF LIGHT SPECTRAL COMPOSITION ON THE LENGTH AND WEIGHT OF THE GAMETOPHYTE OF *POLYTRICHASTRUM FORMOSUM* (HEDW.) G.L. SMITH, *PLAGIOMNIUM CUSPIDATUM* (HEDW.) T.J. KOP. AND *PLEUROZIUM SCHREBERI* (BRID.) MITT.

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Abstract. The aim of the present study was to examine the influence of light spectral composition on the length and weight of mosses gametophytes: *Polytrichastrum formosum* (Hedw.) G.L. Smith, *Plagiomnium cuspidatum* (Hedw.) T.J. Kop. and *Pleurozium schreberi* (Brid.) Mitt. Plants were grown 31 days in the chambers equipped with LEDs matrices of the same intensity of light (200 μmol $m^{-2} \cdot s^{-1}$), but different spectral composition: white (WL), white-blue (WBL) and red-green-blue (RGBL). It was found that the WBL as compared to RGBL inhibited the growth of the whole gametophytes of *P. cuspidatum* and *P. formosum*. WBL inhibited also rhizoids length of *P. cupsidatum*, in comparison to plants growing on WL and RGBL as well as growth of leaves stalks *P. schreberi* and *P. cuspidatum* as compared to WL. For RGBL fresh weight of plants *P. cuspidatum* was significantly higher than the WBL, while in *P. schreberi* higher than that for WBL and WL. Impact of light quality on the dry matter production was observed only in *P. schreberi*. Effect of spectral composition of light on the length and weight of the gametophyte depends on the species of moss.

Key words: *Polytrichastrum formosum, Plagiomnium cuspidatum, Pleurozium schreberi*, spectral composition of light, mosses, gametophytes, growth

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Introduction

Plants constantly have to adaptable to changing conditions of the environment, including to conditions of the lighting (Gumiński 1990; Lamparter *et al.* 1998; Kern & Sack 1999; Suetsugu & Wada 2003; Huttunen *et al.* 2005; Cerff & Posten 2012). These organisms receive the light signals through specialized photoreceptors (Brigss & Christie 2002; Hetmann & Kowalczyk 2011; Li *et al.* 2012; Matioc-Precup & Cachiță-Cosma 2012), such as phytochromes, cryptochromes and fototropines. With their help, the plants have got the informations about the quantitative and qualitative changes in the composition of the spectral lights and about the time of the light exposure.

Among cryptogamous plants like as mosses, the signals of light are perceived by specialized receptors similar to the signals known in plants vascular. On the molecular level in the genomes of *Funaria* Hedw. and *Physcomitrella* Bruch & Schimp. were detected CRY genes, alike under construction to the genes described in *Adiantum cappillus-veneris* L. and *Arabidopsis thaliana* (L.) Heynh., which regulate the operation of cryptochrome (Suetsugu & Wada 2003). Besides, the construction of structure and expression of genes encoding phytochrome are better known in the mosses (Pasentsis *et al.* 1998; Zeidler *et al.* 1998).

For many species of mosses living in the lowest layers of the forest, the direct sun rays get to them in a small degree. And some moss species have thin lipid layer that protects them from the damaging effects of light. Others

Fig. 1. Gametophytes of the mosses: **A** – *Plagiomnium cuspidatum*; **B** – *Polytrichastrum formosum*; **C** – *Pleurozium schreberi.*

mosses in response to light stress produce secondary metabolites in the form of flavonoids, with a composition similar to the compounds collected in plants vascular (Huttunen *et al.* 2005).

The aim of the present study was to examine the influence of light spectral composition on the length and weight of gametophytes of such mosses as: *Plagiomnium cuspidatum* (Hedw.) T.J. Kop.(Fig.1 A) , *Pleurozium schreberi* (Brid.) Mitt. (Fig.1 C) and *Polytrichastrum formosum* (Hedw.) G. L. Sm.(Fig. 1 B).

Material and methods

In the experiment, three species of moss were selected from the forest near Cracow (Southern Poland). The moss *P. cuspidatum* occurs naturally in shady habitats, in forests, on rocks and dead wood, *P. schreberi* and *P. formosum* live in coniferous and mixed forests. These species are capable of conducting the process of photosynthesis only in above-ground, haploid gametophyte, built with the stalk with leaves (Szafran 1963; Szweykowska & Szweykowski 2002).

The species of mosses were placed in plastic containers and then transferred to the chambers, with the different colors of light. LED matrices were the source of lights: white (WL-White Light), blue (WBL-White Blue Light), red (RGBL-Red Green Blue Light) with high-intensity red light. The light intensity in chambers was 200 micromol · m^{-2} · s^{-1} (Fig. 2).

Mosses were grown in chambers by 31 days in temperature 18 / 14°C (day / night) at a photoperiod of 12 / 12 h (light / dark), and 80-90 % relative humidity (day / night). The biometric analyses were performed for each species on the 30 repetitions, between individuals the similar most to each other in terms of morphology.

The results represent the average of 30 replicates, with a standard deviation (± SD). The significance of differences between means were tested by – ANOVA (univariate analysis,

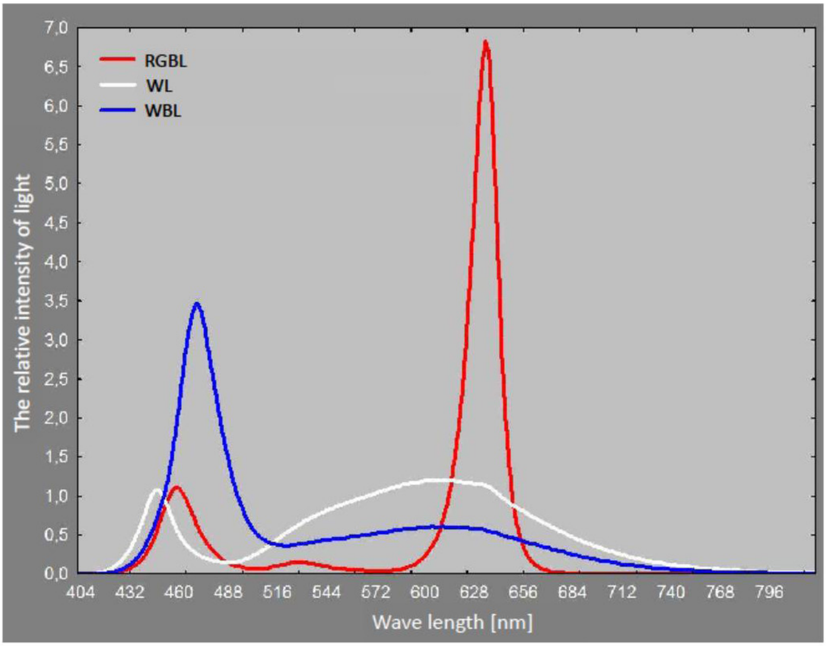

Fig. 2. The spectral composition of light colors of LED matrices.

simple). Comparisons of the significance of differences in mean values between objects made using Tukey's test for homogeneous groups, the confidence level of $p \leq 0.05$. Statistical analysis was performed using Statistica 9.0 for Windows.

Results and discussion

The processes of metabolic in plants depend largely on the type and intensity of light. In darkness and in low intensity of light plants grow vigorously, but in the full light their growth is inhibited (Pilarski 2005). The spectral composition of light reaching the Earth's surface varies depending on time of day, year, geographical location, altitude and the exposure position (Wang *et al.* 2009; Skoczowski *et al.* 2010).

The analyses have shown that the spectral composition of light affects the total length gametophyte in some the species of mosses. In the case of mosses *P. cuspidatum* the longest gametophyte had plants growing under RGBL, and the shortest in light WBL (Fig. 3 A). In *P. formosum* was observed statistically significant differences in the average length of the gametophyte only between the plants growing in the light RGBL and WBL. As in the case of *P. cuspidatum*, the light WBL inhibited the growth of the aerial parts gametophytes *P. formosum* (Fig. 3 B). In *P. schreberi* wasn't observed the effect of spectral composition of light on average length of gametophytes (Fig. 3 C). In light WBL the inhibition of growth rhizoids and stalks with leaves in *P. cuspidatum* was observed. In this case, the length of the gametophytes was significantly lower than in mosses growing in other light conditions. The spectral composition of light also caused significant differences in the average length of stalks with leaves in *P. schreberi*, whose growth was strongly inhibited by light RGBL (Tab. 1.).

The spectral composition of light also had an impact on the mean values of fresh and dry weight of gametophytes some species of moss. Significantly higher values fresh weight was observed for the gametophyte *P. cuspidatum* in light RGBL, in comparison to the plants growing in light WBL (Fig. 4 A). Similar differences were observed between plants *P. schreberi* in the light WL, compared to plants in WBL conditions (Fig. 4 C). Significant difference in

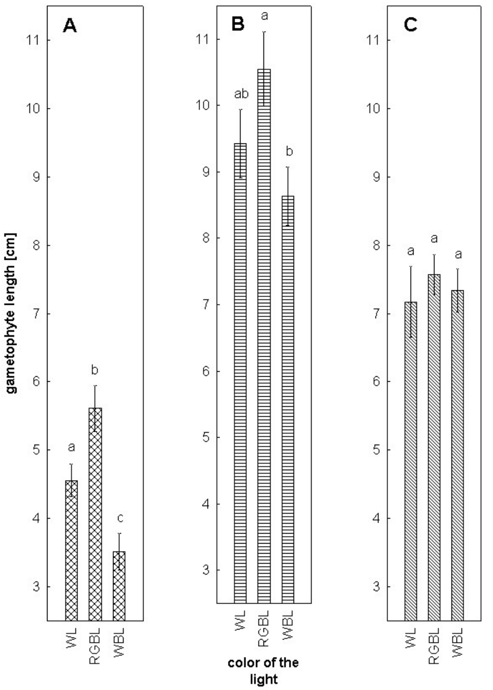

Fig. 3. Impact of spectral composition of light on the gametophyte (cm) in *Plagiomnium cuspidatum* (**A**), *Polytrichastrum formosum* (**B**) and *Pleurozium schreberi* (**C**). The mean values of 30 replicates ± SD. Values with different letters are substantially different at $p \leq 0.05$ by Tukey's procedure for homogeneous groups – Tukey test (HSD).

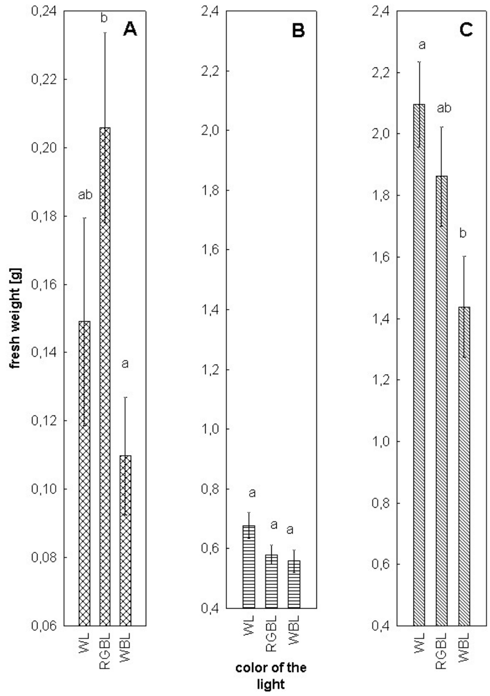

Fig. 4. Impact of spectral composition of light on the fresh weight (g) in *Plagiomnium cuspidatum* (**A**), *Polytrichastrum formosum* (**B**) and *Pleurozium schreberi* (**C**). The mean values of 30 replicates ± SD. Values with different letters are substantially different at $p \leq 0.05$ by Tukey's procedure for homogeneous groups – Tukey test (HSD).

dry weight content was observed only between gametophytes *P. schreberi*, had grown in the light of WL and WBL (Fig. 5C).

Conclusions

The unfavorable environmental factors which disrupt the course of metabolic and physiological processes of plants cause the reversible and irreversible changes in bodily functions (Rzepka 2008). In forest the light is the most variable physical factor, because the sun's rays are reaching the forest not only with altered intensity but also about the different spectral composition of light. The light signals are one of the most important environmental stimuli regulating plant growth. In addition to the amount of light the plants measure the quality, direction and frequency of the incident light rays, and uses this information to optimize

Table 1. Impact of spectral composition of light on the length of rhizoids and stalks with leaves in *Plagiomnium cuspidatum* (**Pc**), *Polytrichastrum formosum* (**Pf**) and *Pleurozium schreberi* (**Ps**). The mean values of 30 replicates ± SD. Values with different letters are substantially different at $p \leq 0.05$ by Tukey's procedure for homogeneous groups – Tukey test (HSD).

Color of light	WL			RGBL			WBL		
Species of mosses	Pf	Pc	Ps	Pf	Pc	Ps	Pf	Pc	Ps
Length of rhizoids (cm)	4.0^{a}	1.1^{a}	4.0^{a}	5.1^{a}	1.2^{a}	4.3^{a}	3.9^{a}	0.7^{b}	3.9^{a}
Length stalks with leaves (cm)	6.6^{a}	3.4^{a}	5.6^{a}	5.6^{a}	3.6^{a}	3.4^{b}	5.8^{a}	2.0^{b}	4.2^{c}

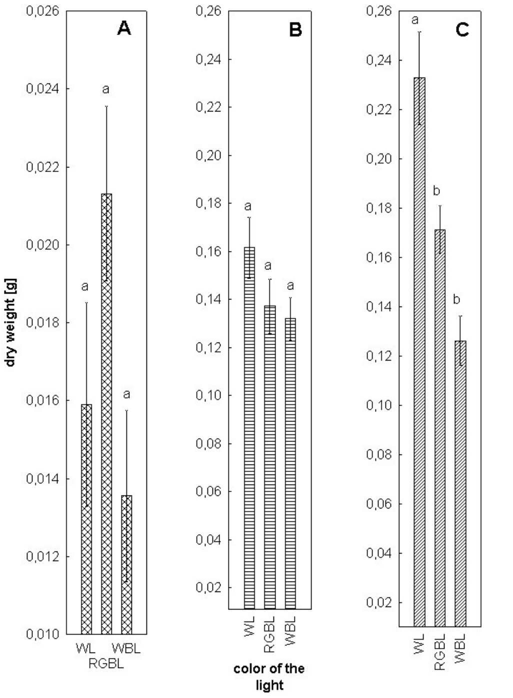

Fig. 5. Impact of spectral composition of light on the dry weight (g) in *Plagiomnium cuspidatum* (**A**), *Polytrichastrum formosum* (**B**) and *Pleurozium schreberi* (**C**). The mean values of 30 replicates ± SD. Values with different letters are substantially different at p ≤ 0.05 by Tukey's procedure for homogeneous groups – Tukey test (HSD).

growth and development to the prevailing environmental conditions (Franklin *et al.* 2005).

Studies conducted have confirmed a significant impact the spectral composition of light on the length and weight of the gametophytes choosen species of moss. It has been shown that the light can controlled the growth of the aerial parts gametophytes, while no effect on the growth of rizhoids. The exception is moss *P. cuspidatum*, in which the growth of these anatomical parts was inhibited under conditions of light WBL.

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