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The Effect of Light on the Content of Photosynthetically Active Pigments in Plants. VII. Chromatic Adaptation in the Lichens *Peltigera polydactyla* and *P. rufescens*

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Summary

CZECZUGA B. 1987. The effect of light on the content of photosynthetically active pigments in plants. VII. Chromatic adaptation in the lichens *Peltigera polydactyla* and *P. rufescens*. – Phyton (Austria) 26 (2): 201–208, with 1 figure. – English with German summary.

The photosynthetic pigments (phycobiliproteins, chlorophyll a and carotenoids) in *Peltigera polydactyla* and *P. rufescens* as chromatic adaptation were examined.

The total content of the phycobiliprotein pigments was highest during autumn and winter, but in spring and summer the general content this pigments decreased.

The concentration of C-phycocyanin increased during autumn and winter and decreased in summer whereas C-phycoerythrin increased.

The biggest total content of phycobiliproteins pigments was observed in the thalli of the investigated lichens when red and blue light was used.

The highest content of chlorophyll a and carotenoids in thalli of *Peltigera rufescens* was found in the yellow and blue light.

Zusammenfassung

CZECZUGA B. 1987. Einfluß des Lichtes auf den Gehalt photosynthetisch aktiver Farbstoffe bei Pflanzen. VII. Chromatische Adaptation der Flechten *Peltigera polydactyla* und *P. rufescens*. – Phyton (Austria) 26 (2): 201–208, mit 1 Abbildung. – Englisch mit deutscher Zusammenfassung.

Der Gehalt der photosynthetisch aktiven Farbstoffe (Phycobiliprotein, Chlorophyll a und Carotenoide), in den Flechten *Peltigera polydactyla* und *P. rufescens* wurde im Aspekt der chromatischen Adaptation untersucht.

Der höchste Gesamtgehalt der Phycobiliproteinfarbstoffe wurde im Herbst und Winter beobachtet, wogegen im Frühling und Sommer der Phycobiliproteingehalt sank.

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Der C-Phycocyaningehalt stieg im Herbst und Winter an und sank im Sommer, wogegen der C-Phycoerythringehalt im Herbst und Winter sank.

Der höchste Gesamtgehalt der Phycobiliproteinfarbstoffe wurde in den Flechten im roten und im blauen Licht beobachtet.

Die höchste Konzentration des Chlorophyll a und der Carotinoide zeigte *Peltigera rufescens* im gelben und blauen Licht.

Introduction

Examinations on the influence of light of different wave length on the contents of chlorophylls and carotenoids in unicellular green algae showed increase of these pigments in the short wave light and first of all in the green light (CZECZUGA 1977, CZECZUGA & al. 1980). Further examinations showed that the chlorophyll and carotenoid contents markedly increases also in the range of short waves in green algae phycobiont (CZECZUGA 1981). It especially concerns the blue light.

Due to the fact that blue-green algae of *Nostoc* genus are considered as phycobionts in lichens of *Peltigera* genus it was interesting to examine the influence of light of different wave length on the active photosynthetic pigments which as it is known are different from those of green algae. Among others the differences concern chlorophyll because only chlorophyll a is found, the carotenoids content is different, and first of all blue-green algae include active photosynthetic pigments which are phycobilins and which are not found in green algae.

Besides the total content of phycobiliprotein pigments and percentage content of particular pigment in particular months were determined.

Material and Methods

Two species of lichen i. e. *Peltigera polydactyla* (NECK.) HOFFM. and *P. reufescens* (Weis.) HUMB. were used in the examinations. *P. polydactyla* was collected once a month from an open area well exposed to the sun light (the airfield in Bialystok), and the samples of *P. rufescens* were always collected from two sites at the bottom of a trunk of an aspen tree at the edge of a mixed wood. The southern site was well exposed to the sun's rays, whereas the thalli from the northern flank were only partly insolated. The thalli of the lichens together with unmoved breeding ground were put into glass containers and located into special boxes furnished with appropriate glass filters. The filters were manufactured by the FPN-Bytom Works, wavelengths being indicated by the producers. Four basic colours were put to use: red ($\lambda = 700$ nm), yellow ($\lambda = 590$ nm), green ($\lambda = 500$ nm) and blue ($\lambda = 450$ nm). A culture of every species of lichens grows in a box provided with usual, "colourless" (white), glass served for control (CZECZUGA 1977, 1981). From time to time the examinated thalli were sprayed with water. As source of light served glass lamps (5.4 $W \cdot m^2$) and daylight from the window (1.2 $W \cdot m^2$, jointly 6.6 $W \cdot m^2$), the time of illumination amounted to 10

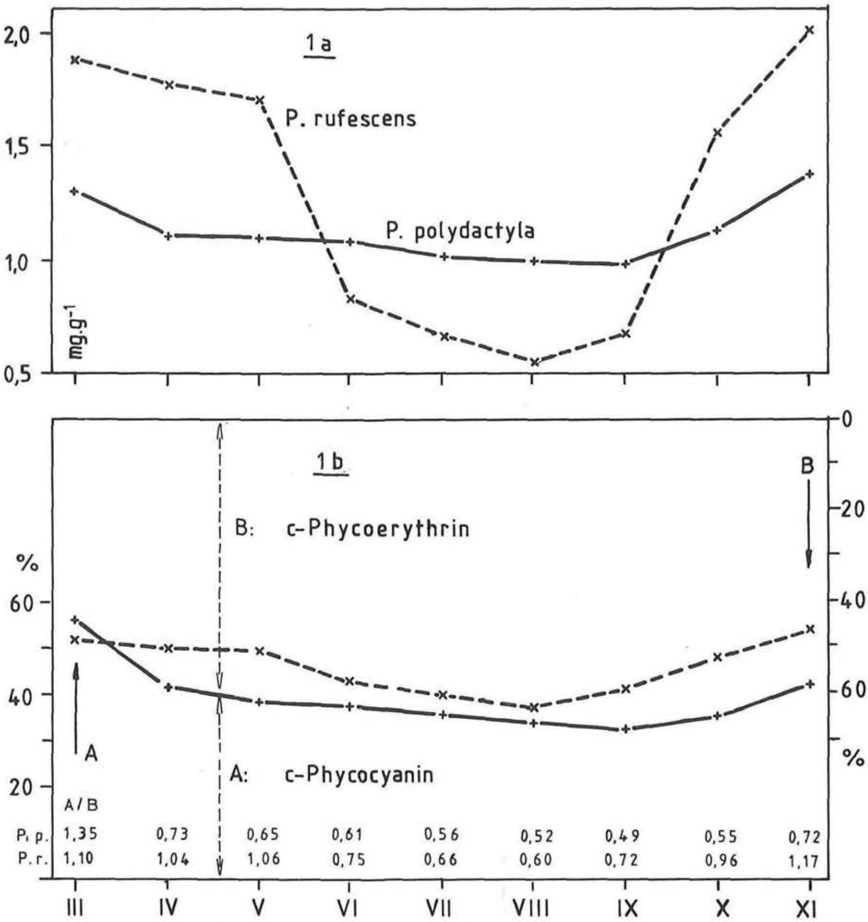

Fig. 1 a. Content of phycobiliproteins (mg · g^{-1} dry weight, means of 3 determinations) of *Peltigera polydactyla* (P. p., solid line) and of *Peltigera rufescens* (P. r., broken line) March – November.

Fig. 1 b. *Peltigera polydactyla* and *P. rufescens* (Symbols see Fig. 1 a): Relative shares (in percents of the total pigment content as indicated in Fig. 1 a) of C-phycocyanin (A, from the abscissa to the respective curve) and of C-phycoerythrin (B, from the respective curve to 100), and the ratio A/B (numbers along the basis line).

hours a day, the ratio of L to D was as 10 to 14. The relative light intensites after passing through the filters were: colourless light 95.5%, red 62.6%, yellow 21.1%, green 13.2% and blue 7.9% of the 6.6 W · m^{-2} in front of every thalli of the lichens. The light intensity measurements were made by means of a luxometer, 1 lx = 0.004 W · m^{-2} being applied.

The total amount of the phycobiliprotein pigments and the percentage content at the particular pigments were determined after 21 days of the experiment. Isolation of the particular phycobiliproteins was carried out using the Sephadex G-100 chromatography method (CZECZUGA 1985) and the percentage of the particular pigments was determined using the methods of BENNETT & BOGORAD (1973). The total contents of chlorophyll a and carotenoids were determined by the method of JEFFREY & HUMPHREY (1975).

Results

Figure 1 a shows the changes of the total content of the phycobiliprotein pigments during the year. Both the thalli of *P. polydactyla* and *P. rufescens* included the highest concentration of these pigments during late autumn and winter, i. e. in the period when the insolation was minimal. But in spring and summer the total content of the phycobiliprotein pigments decreased. Besides the concentration of C-phycocyanin increased during autumn and winter and summer the concentration of C-phycocyanin decreased whereas C-phycoerythrin increased (Fig. 1 b).

The fact is confirmed by the content of those two biliprotein pigments in the thallum *P. rufescens* from quite a different environment, namely,

Table 1

The phycobiliproteins content in *Peltigera rufescens* from different sites (June)

	south part of trunk (S)	northern part of trunk (N)	ratio N/S
Total content of phycobiliproteins in mg · g^{-1} dry weight (means from 3 determinations)	1.146	1.723	1.22
C-phycocyanin (%)	40.0	43.8	1.10
C-phycoerythrin (%)	60.0	56.2	0.94

Table 2

Peltigera polydactyla and *P. rufescens:* Phycobiliproteine content (mg · g^{-1} dry weight, means from 3 determinations), and the relative shares of C-phycocyanin and C-phycoerythrin (in %) in dependence on the light quality

Filter	Total content		C-phycocyanin (%) A		C-phycoerythrin (%) B		Ratio A/B	
	P. polydactyla	P. rufescens	P. polydactyla	P. rufescens	P. polydactyla	P. rufescens	P. polydactyla	P. rufescens
White	1.067	1.160	63.2	62.1	36.8	37.9	1.72	1.64
Red	1.213	2.100	59.9	62.9	40.1	37.1	1.49	1.70
Yellow	1.185	1.295	58.3	61.8	41.7	38.2	1.40	1.62
Green	1.152	0.985	56.3	42.2	43.7	57.8	1.29	0.73
Blue	1.726	1.445	58.7	46.4	41.3	53.6	1.42	0.87

from the south and northern part of the trunk of the aspen, where grown this lichen (Table 1).

Examinations on the concentration of phycobiliprotein pigments showed differences when using different filters (Table 2). The highest concentration of the phycobiliprotein pigments was observed when using the blue and red *(P. polydactyla)*, red and blue filters *(P. rufescens)* respectively. Contents of the particular phycobiliproteins were altered as follows: C-phycocyanin increased in the thalli of *P. rufescens* and *P. polydactyla* when using the red filter and C-phycoerythrin increased when using the green filter.

Examinations on the content of chlorophyll a and total content of carotenoids showed the highest concentration of chlorophyll a and carotenoids in the thalli of *P. rufescens* when using the yellow and blue filters (Table 3).

Table 3

Peltigera rufescens: Chlorophyll a – and carotenoid content in dependence on light quality (mg · g^{-1} dry weight, means from 3 determinations)

Filter	A: Chlorophyll a mg	(%)	B: Carotenoids mg	(%)	Ratio A/B
white	0.604	(100.0)	0.237	(100.0)	2.54
red	0.651	(107.7)	0.267	(112.6)	2.43
yellow	0.907	(150.1)	0.367	(154.8)	2.47
green	0.569	(94.2)	0.270	(113.9)	2.10
blue	0.872	(144.3)	0.339	(143.0)	2.57

Discussion

As it is known blue-green algae of *Nostoc* genus are considered as phycobionts in lichens of *Peltigera* genus. The following *Nostoc* species have been identified up to now in lichens of *Peltigera* genus: *Nostoc commune, N. muscorum, N. sphaericum* and *N. punctiforme* (Linkola 1923, Degelius 1954, Bergman & Hällbom 1982). Examinations on the incidence of the particular phycobiliprotein pigments in blue-green algae of *Nostoc* genus (Hattoti & Fujita 1959, Gray & Gantt 1975, Los 1980, Zilinskas 1982) showed the presence of phycoerythrin, phycocyanin and allophycocyanin. Analysis of phycobiliproteins in *P. polydactyla* and *P. rufescens* (Czeczuga 1982) showed the presence of C-phycoerythrin, C-phycocyanin in thalli of these lichens and allophycocyanin-B only in thalli of *P. rufescens*. In recent years in the colls of free-living *Nostoc* sp. individuals, apart from allophycocyanin-B, other forms of this pigment have been found which differ form one another in their maximum absorption and aminoacid composition of the protein part (Troxler & al. 1980). These pigments are: allophycocyanin I (absorption maximum 654 nm), allophycocyanin II (648 nm) and allophycocyanin III (650 nm). As it is known phycobiliprotein in algae are the complementary pigments in the process of photosynthesis, they absorb the light energy and then deliver it to chlorophyll a (STADNICHUK & GUSEV 1979, TANDEAU DE MARSAC 1983). The pigments are collected in special structures called phycobilisomes. The distribution of particular pigments in phycobilisome is following: phycoerythrin is found in the external part of phycobilisome, phycocyanin in the middle part and allophycocyanin in the layer next to the photosynthesizing membrane (STADNICHUK & GUSEV 1979). So the energy absorbed by phycoerythrin is delivered to phycocyanin and further to allophycocyanin as to reach chlorophyll a. In this system the depedence of the phycobiliprotein pigments concentration on the light intensity becomes understable. When the light is weak the general content of phycoproteins especially of phycoerythrin, increases. It was shown in freeliving blue-green algae (FUGLISTALLER & al. 1981) and *Nostoc* cells (KIPE-NOLT & al. 1982), red algae (LEY & BUTLER 1980) and in cryptomonads (JUPIN & al. 1980). Besides the content of phycoerythrin in the alga cells increases in the green and blue light, i. e. in the short wave light when the growth of the phycobiliprotein pigments is intensively inhibited. The growth of phycocyanin was stimulated by the red-orange light which was shown in free living blue-green and red algae (CZECZUGA 1985). The obtained results of the examination on *Peltigera* lichens are in general similar to the phenomena observed in blue-green or red algae. The weak insolation in autumn and winter results in increase of phycobiliproteins content in the thalli of *P. polydactyla* and *P. rufescens*. In this period the content of C-phycocyanin also increases. On the other hand the general content of phycobiliprotein pigments decreases in spring and summer but the content of C-phycoerythrin is relatively high. Examinations on the content of the phycobiliprotein pigments in the thalli of *P. polydactyla* and *P. rufescens* when illuminated by the light of different wave length showed that the general picture of changes of particular phycobiliproteins is similar to that observed in free – living blue-green algae.

The increase of chlorophyll a and total content of carotenoids was observed in *Anabaena cylindrica* and *A. variabilis* when using the yellow filter, the increase was slightly smaller when the green filter was used (CZECZUGA 1986 a). The highest concentration of chlorophylls and carotenoids was found when using the blue filter in lichens *Hypogymnia tubulosa* and *Parmelia caperata* in which green algae of *Trebouxia* type are considerad as phycobionts (CZECZUGA 1981). The free-living water green algae of *Chlorella* and *Scenedesmus* genus show the highest concentration of these pigments when using the green filter (CZECZUGA & al. 1980), but the unicellular epiphyte *Desmococcus vulgaris,* a green algae as well of the tree bark-when using the yellow filter (CZECZUGA 1986 b).

Summarizing it should be said that the increased concentration of the pigments participating in photosynthesis when using different light intensity or particular wave length is an adaptation to the changeable illumination conditions during the year in general and to the different spectral composition in a given environment in particular. Studies carried out on free-living cells of *Nostoc* sp. have shown that morphological changes of cells (Isono & Fujita 1981) and colourless polypeptides present in the phycobilisomes also take part in their chromatic adaptation (Zilinskas & Howell 1983).

As recent studies have shown, in the ecological adaptation of lichens, not only pigments participate but also photosynthetic and respiration proces (Ino 1985). Lichens collected in the Antarctic were adapted to cool condition and some species collected in subalpine zones were adapted to warm condition. For example, the optimal temperatures for net photosynthetic rates in Antarctic lichens were lower than 5° C and those in lichens which lived on rock surface at a southern slope in mountains of Japan were higher than 20° C.

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