
PHOTOSYNTHETIC RESPONSE WITH RESPECT TO LIGHT IN THREE STRAINS OF LICHEN ALGAE^{1, 2}

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ABSTRACT

Net photosynthetic rates of three lichen algae were studied at different light intensities. Algae from lichens with a pigmented cortex exhibited decreased net photosynthetic rates at high light intensities, while algae from a non-pigmented lichen were light-tolerant. The physiology of lichen algae appeared to be related to the pigmentation and ecological behavior of the lichen thallus.

INTRODUCTION

The biology of the lichen association is a stimulating topic for research and much work has been done on the physiological relationships of the symbionts (Ahmadjian, 1967; Hale, 1967; Smith, 1962). However, light-compensation and light-saturation points for isolated symbionts have not been determined. In addition, possible relationships between these measurements and habitat or thallus pigmentation have not been investigated. Some preliminary data on these topics are presented here as a result of studies on three strains of the phycobiont *Trebouxia* from lichens collected in central Ohio.

MATERIALS AND METHODS

Lichen Algae

Trebouxia Pyum. phycobionts of the lichens *Cladonia cristatella* Tuck., *Caloplaca holocarpa* (Hoffm.) Wade, and *Lecanora dispersa* (Pers.) Somme. were isolated and cultured axenically by the techniques of Ahmadjian (1967). Phycobionts were grown on agar slants of *Trebouxia* Organic Nutrient Medium I (Ahmadjian, 1967) and kept in a growth chamber where the daily temperature cycled between 11 and 19°C. Cultures were kept in darkness, as it was thought that more uniform cultures would result. Twelve-week-old cultures of all three phycobionts were used for physiological studies.

Respirometry

Respiratory and net photosynthetic rates of the same plants were measured in a 1.3% CO₂ (v/v) atmosphere by differential respirometry. The instrument

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consisted of all-glass volumeters placed in a Gilson Differential Respirometer unit. Changes in O_2 volume were measured while CO_2 was held constant with Pardee buffer (Umbreit, Burris, & Stouffer, 1964). Temperature in the respirometer water bath was $20^\circ C$ and light intensities of 0, 0.2, 1.1, 3.4, 7.4, and 12.0 mW cm^{-2} (measured with a Yellow Springs Instruments Model 65 radiometer and a 65-51 sensor) (12.0 mW cm^{-2} corresponds to $0.172 \text{ cal cm}^{-2} \text{ min}^{-1}$, or about 13,500 lux) were furnished by a bank of incandescent lamps. Phycobionts were prepared for study by being scraped from the agar surface, suspended in 4 ml of Bold's solution (Ahmadjian, 1967), and allowed to equilibrate overnight in darkness before oxygen exchange was measured. Net photosynthetic rates (microliters of oxygen exchanged per milligram of dry weight of algae per hour) of six replicate samples of each alga were measured for a period of one hour at each light intensity. Light curves were determined for each phycobiont by plotting the mean net photosynthetic rate against light intensity.

Chlorophyll Determination

Phycobiont chlorophyll was extracted by the method of Rao and LeBlanc (1965). Algae (300–500 mg fresh weight) were homogenized in a glass tissue-grinder and chlorophyll was extracted with acetone:water (80% v/v). Optical density measurements of the acetone solutions were made with a Gilford model 2000 spectrophotometer at 645 and 663 nm, following which chlorophyll *a*, chlorophyll *b*, total chlorophyll, and the *a/b* ratio were determined by the method of Arnon (1949).

RESULTS

Respiratory and net photosynthetic rates of the phycobionts studied were quite different (Table 1). Light curves of the phycobionts (fig. 1) show that the

TABLE 1

Mean net photosynthetic rates of phycobionts at different light intensities. Rates were measured at $20^\circ C$, 1.3% CO_2 , and are expressed as the net microliters of oxygen exchanged per milligram of dry weight of algae per hour. A negative rate indicates respiration. Each value is a mean of 6 samples \pm standard deviation.

Light Intensity (mW cm^{-2})	Phycobiont of <i>Cladonia cristatella</i>	Phycobiont of <i>Caloplaca holocarpa</i>	Phycobiont of <i>Lecanora dispersa</i>
0	-1.49 \pm .29	-.77 \pm .04	-.96 \pm .09
0.2	-.78 \pm .18	-.72 \pm .10	-.66 \pm .08
1.1	+.81 \pm .13	+.10 \pm .10	+.23 \pm .10
3.4	1.72 \pm .35	1.45 \pm .22	1.98 \pm .27
7.4	1.72 \pm .34	1.15 \pm .16	1.86 \pm .30
12.0	1.71 \pm .36	.95 \pm .16	1.44 \pm .23

light-compensation points, where photosynthesis and respiration are equal, are similar. The light-saturation points (points of maximum photosynthetic activity) are also similar. However, photosynthetic responses to high light-intensities are appreciably different. Phycobionts of *Lecanora dispersa* and *Caloplaca holocarpa* appear to be sensitive to strong light, as shown by decreasing photosynthetic rate, while the phycobiont of *Cladonia cristatella* is tolerant to light intensity up to 12 mW cm^{-2} .

Chlorophyll contents of the phycobionts (Table 2) differ greatly. Phycobionts of *Cladonia cristatella* and *Lecanora dispersa* have about the same chlorophyll contents, whereas the phycobiont of *Caloplaca holocarpa* contains almost twice the amount of chlorophyll *a* as the other species.

TABLE 2

Chlorophyll contents of *Trebouxia phycobionts* expressed as micrograms of chlorophyll per gram of fresh weight of algae. Mean of 5 samples \pm standard deviation.

Organism	Chl a	Chl b	Total Chl	a/b
<i>Cladonia cristatella</i>	358 \pm 109	171 \pm 69	529 \pm 169	2.19 \pm .52
<i>Caloplaca holocarpa</i>	625 \pm 21	142 \pm 13	767 \pm 10	4.44 \pm .53
<i>Lecanora dispersa</i>	354 \pm 131	140 \pm 45	485 \pm 177	2.51 \pm .19

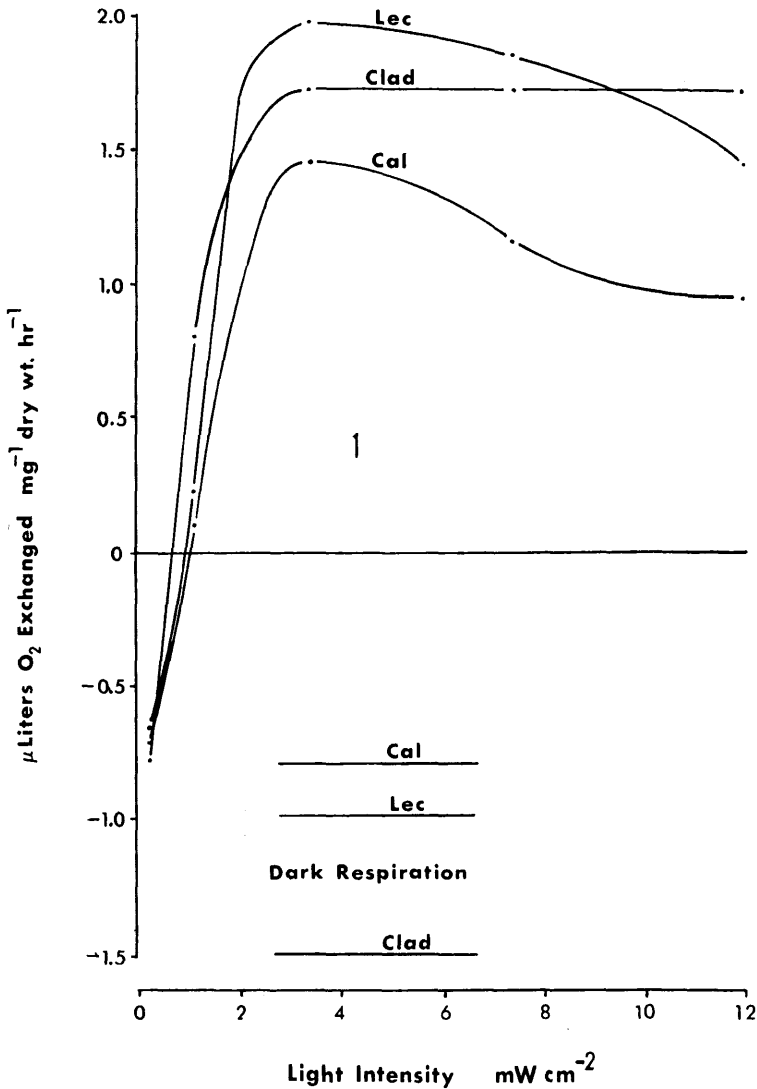


FIGURE 1. Photosynthetic light curves of *Trebouxia* phycobionts from the lichens *Cladonia cristatella* (Clad), *Caloplaca holocarpa* (Cal), and *Lecanora dispersa* (Lec). Measurements were made at 20° C and 1.3% CO₂.

DISCUSSION

These results show that cultured *Trebouxia* strains have noticeable physiological differences. Ahmadjian (1970) has divided the genus *Trebouxia* into two groups, based on morphological and ultrastructural differences. It is interesting to note that the phycobiont of *Cladonia cristatella*, which belongs to Group I, is more light-tolerant than are phycobionts from the crustose lichens, which are members of Group II. Results presented here also support the hypothesis of earlier workers (Ahmadjian, 1962) that phycobionts are sensitive to high light-intensities. Light intensities greater than 5 mW cm^{-2} , only about 6% in full sunlight (at noon on a clear midsummer day), caused decreasing net photosynthetic rates in two of the phycobionts studied.

Interpretation of these results with respect to pigmentation and ecology of the composite thallus is difficult. Previous studies have shown that physiological responses of cultured phycobionts and lichenized phycobionts are markedly different (Drew and Smith, 1966). The mycobiont is thought to exert some influence over the physiology of the phycobiont (Kinraide and Ahmadjian, 1970), although the extent of this control is uncertain. In addition to these possibilities, algal physiology may have been altered by the cultural and experimental conditions used. Relative comparisons of the three phycobionts, however, are valid, since they were all subjected to the same treatment. If caution is exercised, phycobiont physiology may also be related to characteristics of the composite thallus.

The dense cortical pigmentation of the crustose lichens, *Lecanora dispersa* and *Caloplaca holocarpha*, does appear to function as a screen for the algal layer below, since both lichens usually grow in full sunlight and the photosynthetic rate of both phycobionts is retarded by strong light. Conversely, the light-tolerance of the *Cladonia cristatella* phycobiont may reflect the unpigmented cortex of the whole thallus, and its wide variety of habitats, from shade to full sunlight. In conclusion, the present study indicates that physiological capabilities of the phycobiont are related to habitat, and to pigmentation of the composite thallus.

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