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2.3 Temperature Response of Antarctic Cryptoendolithic Photosynthetic Microorganisms

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Summary: Growth responses to temperatures between 12.5 C and 25° C were determined for five photosynthetic microorganisms isolated from the Ross Desert cryptoendolithic community. Among eukaryotic algae, two strains of *Trebouxia* sp. have an upper temperature limit of 20° C, and two strains of *Hemichloris antarctica* of 25° C. The cyanobacterium *Chroococcidiopsis* sp., in contrast, grows at temperatures above 25° C. These and earlier studies suggest that the eukaryotic algae of the Antarctic cryptoendolithic community have an upper temperature limit near 25° C.

Zusammenfassung: Von 5 photosynthetischen kryptoendolithischen Mikroorganismen der Ross Desert wurde der Temperaturbereich des Wachstums bestimmt. Unter den eukaryotischen Algen hatten 2 *Trebouxia* spec.-Stämme ihre Wachstumsgrenze bei 20° C. Hingegen zeigt das Cyanobacterium *Chroococcidiopsis* spec. noch Wachstum bei über 25° C. Diese und frühere Untersuchungen weisen darauf hin, daß die obere Temperaturgrenze eukaryotischer kryptoendolithischer Algen nahe 25° C liegt.

1. INTRODUCTION

The existence of cryptoendolithic microorganisms in the McMurdo Dry Valleys of Antarctica (Ross Desert) was first reported by FRIEDMANN & OCAMPO in 1976. General features of the ecosystem were described by FRIEDMANN (1982); communities and organisms were surveyed by FRIEDMANN et al. (1989). Studies of the nanoclimate of the microbial habitat (KAPPEN et al. 1981, FRIEDMANN et al. 1987a) and of the physiology of the community (KAPPEN & FRIEDMANN 1983, VESTAL 1988) suggest that for most of the time, metabolic activity takes place at low temperatures around 0° C and below. These organisms are evidently adapted to low temperature ranges. MORITA (1975) considers microorganisms growing at 0° C and below with an upper temperature limit of approximately 20° C to be psychrophilic and those with a higher temperature limit to be psychrotrophic. Observations during maintenance of cultures isolated from the Antarctic cryptoendolithic community indicate that, although fungal isolates and at least some cyanobacteria are not particularly temperature sensitive, eukaryotic algae are damaged during prolonged exposure to room temperature.

SCHOFIELD & AHMADJIAN (1972) found that six *Trebouxia* strains isolated from coastal Antarctic lichens have an optimum temperature around 12° C and a maximum of 20° C. SEABURG et al. (1981) studied the temperature response of 35 taxa and 128 clonal cultures of Antarctic algae, including 41 strains of cyanobacteria, from different habitats. Thirty-one strains had a temperature limit of 20° C or lower, 52 strains grew at temperatures up to 25° C and 45 strains grew at higher temperatures. Two microalgae of the Antarctic cryptoendolithic community studied to date, show psychrophilic character: The upper temperature limits of growth in four *Hemichloris antarctica* strains were reproted as 20° C, with no growth at 22.5° C and cell damage or death at 25° C (TSCHERMAK-WOESS & FRIEDMANN 1984). Two strains of the xanthophycean alga *Heterococcus endolithicus* Darling & Friedmann have a temperature range of –4° C to 22° C, with an optimum between 1° C and 18° C. Other Antarctic *Heterococcus* species, which are not members of the Ross Desert cryptoendolithic community (*H. pleurococcoides* Pitschmann, *H. caespitosus* Vischer, and *H. protonematoides* Vischer), have similar optimal temperatures for growth, but their maximum temperature is above the psychrophilic range (DARLING et al. 1987).

In this study, we investigated the temperature responses of five photosynthetic members of the cryptoendolithic community.

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2. METHODS

The strains (Table 1) are being maintained in the Culture Collection of Microorganisms from Extreme Environments (CCMEE) at the Polar Desert Research Center, Florida State University. They were grown at 4° C in liquid Bold Basal Medium (for eukaryotic algae) or BGII (for *Chroococcidiopsis*) until log phase; 25 ml aliquots were added as inoculum to 75 ml of sterile medium in 125 ml Erlenmeyer flasks, then placed on a temperature-gradient table under cool white fluorescent light with a continuous illumination of 20 µmole photons $m^{-2} s^{-1}$.

CCMEE strain number	Name	Source	Isolator*
(134) A767-47	*Chroococcidiopsis* sp.	Cryptoendolithic in sandstone boulder, floor of Beacon Vally	ROF
(177) A790-17	*Trebouxia* sp.	Phycobiont of *Acarospora gwynnii* Dodge Rudolph, cryptoendolithic (?) in sandstone, Linnaeus Terrace	ROF
(181) 29 aA15	*Trebouxia* sp.	Soil (depth 1 cm), valley W. of Oliver Peak, 1430 m alt., 77°37'S, 160°54'E	HSV
(190) A789-45	*Hemichloris antarctica*	Cryptoendolithic in sandstone, Mt. Dido	ROF
(193) A801-142	*Hemichloris antarctica*	Cryptoendolithic in sandstone, Linnaeus Terrace	ROF

Table 1: Strain Histories. *ROF = R. O. Friedmann; HSV = H. S. Vishniac.

Six replicate cell samples were counted with a hemacytometer. In the organisms studied, populations consist of a mixture of single cells and reproducing cells, which contain a varying number of young cells (baeocytes in *Chroococcidiopsis* and autospores in *Trebouxia* and *Hemichloris*) in various stages of development. For this reason, the variance in cell counts in these organisms is greater than in randomly distributed cells such as in most heterotrophic bacteria. The present study deals only with the upper temperature ranges of growth. We know that photosynthetic activity in this community extends to –8° C (KAPPEN & FRIEDMANN 1983, and unpublished, VESTAL 1988), but growth at this temperature range is too slow to be measured with accuracy.

3. RESULTS

The results are based on two weeks of growth and are shown (Figure 1) as percentages of initial cell concentration (= 100%). Because the initial counts were not significantly different, the initial values for each strain were pooled for all six temperatures.

Chroococcidiopsis sp., strain (134) A767-47, has a growth curve that is relatively flat and symmetric. The high temperature limit has not been reached in the present study, indicating that this organism is not psychrophilic.

The eukaryotic algae show characteristic psychrophilic growth response. The two *Trebouxia* strains have an optimum at 17.5° C and no growth or substantial decline above 20° C. The growth response of these strains is similar to that of the *Trebouxia* strains studied by SCHOFIELD & AHMADJIAN (1972). The strains of *Hemichloris antarctica* have slightly higher temperature limits. Strains (193) A801-142 and (190) A789-45 have optima between 17.5° C and 20.0° C and no significant growth at 25° C. Under different experimental conditions, such as a longer incubation period with a 16:8 light:dark cycle, bleaching and cell death occurred at 25° C in four strains of *H. antarctica,* which includes strain (193) A801-142 (TSCHERMAK-WOESS & FRIEDMANN 1984).

4. DISCUSSION

SCHOFIELD & AHMADJIAN (1972) and the present study show that Antarctic strains of *Trebouxia* are psychrophilic. These results and the data of TSCHERMAK-WOESS & FRIEDMANN (1984) and DARLING et al. (1987) suggest that all eukaryotic photosynthetic members of the Antarctic cryptoendolithic community are psychrophilic or have temperature maxima up to 25° C, which is slightly above the limit of strict psychrophiles as defined by MORITA (1975).

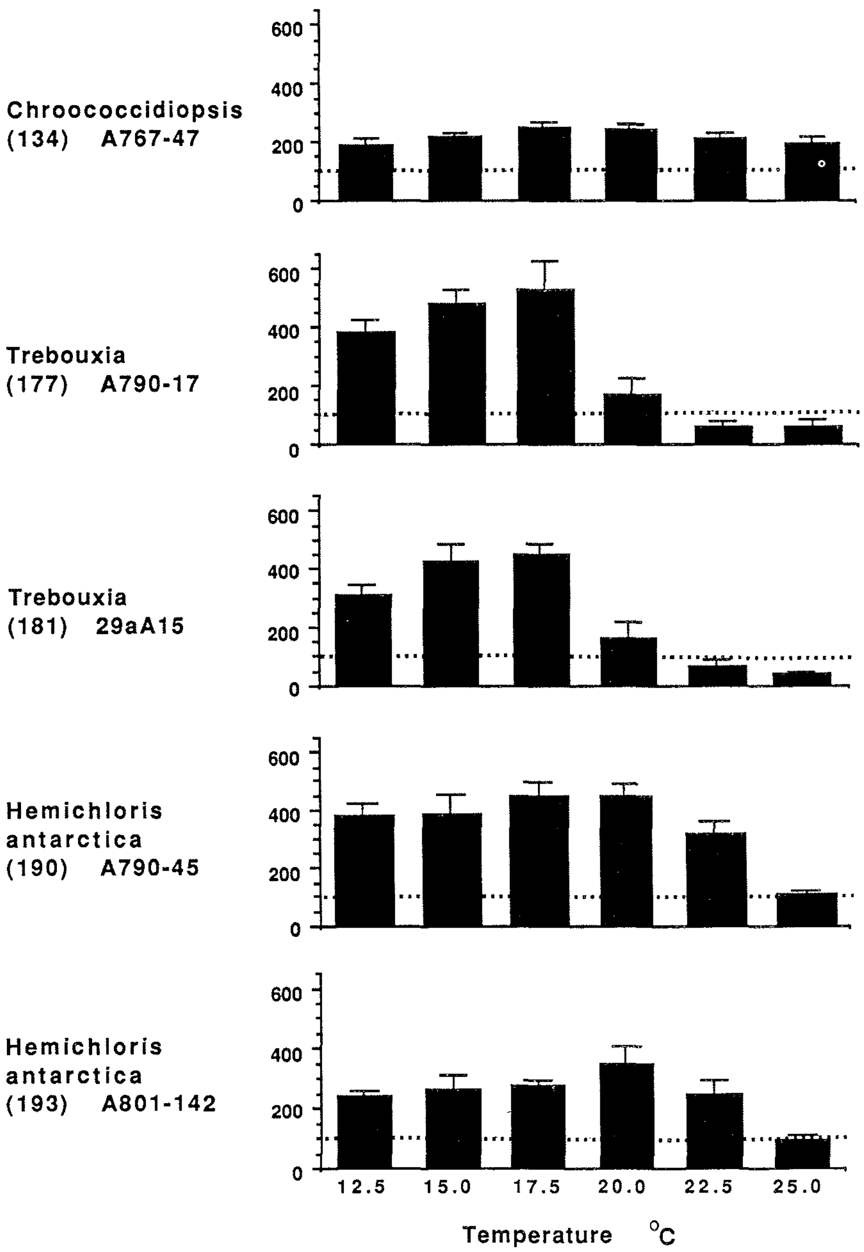

Fig. 1: Percentage and standard error (N=6) of initial cell number (100%, dotted line) of cryptoendolithic photosynthetic microorganisms after two weeks' growth in culture at different temperatures.

The cyanobacterium *Chroococcidiopsis* sp. seems to be the only photosynthetic member of the community that does not show a psychrophilic response. This fact is consistent with the results of DNA/DNA hybridization, indicating that Antarctic cryptoendolithic strains of *Chroococcidiopsis* belong to the same species as those isolated from hot desert rocks (FRIEDMANN et al. 1987b, and unpublished). This organism also differs from the eukaryotic photosynthetic members of the Ross Desert cryptoendolithic community by its extremely low growth rate.

The optimal and upper temperature ranges of cryptoendolithic eukaryotic algae conform with data on ^{14}C incorporation by the entire community (VESTAL 1988). However, temperature otpima for CO_2 balance of the community (KAPPEN & FRIEDMANN 1983, and unpublished) are significantly lower than the optima for growth of the photosynthetic members of the community, as in nature, photosynthetic gain at higher temperatures is more than compensated for by increased respiratory activity. As *Chroococcidiopsis* is only a minor component of the community (FRIEDMANN et al. 1988) it is not expected to significantly influence the temperature range of the overall phtosynthetic activity.

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