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Desert strains of *Chroococcidiopsis*: a platform to investigate genetic diversity in extreme environments and explore survival potential beyond Earth

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Abstract

Cyanobacteria of the genus *Chroococcidiopsis* isolated from hot and cold deserts represent useful models to appreciate life's tricks to withstand extreme desiccation on Earth and to broaden our knowledge of the survival potential of terrestrial organisms beyond Earth. Ongoing researches aim to i) investigate the phylogenetic relationships of *Chroococcidiopsis* strains isolated from hot and cold deserts worldwide; ii) establish their survival potential under extreme terrestrial and extraterrestrial conditions; and iii) develop genetic systems to unravel their DNA repair system.

1. Introduction

In extremely arid hot and cold deserts, such as the Dry Valleys in Antarctica and the Atacama Desert in Chile, cyanobacteria of the genus *Chroococcidiopsis* thrive at the physical limit of life and colonize the last refuges for life within rocks (endolithic growth) or form biofilms at stone-soil-interfaces (hypolithic growth). How they can manage to persist in nature in an ametabolic dry and/or frozen state for the greater part of their life is only partially understood. In addition, they can withstand environmental stressors not currently met in nature, such as doses of ionizing radiation as high as 15 KGy [1]. These features make them proper photosynthetic model organisms to appreciate life's tricks to withstand extreme desiccation on Earth and investigate the survival potential of terrestrial organisms in space or in other planets, such as Mars [2].

2. Genetic diversity among desert strains of *Chroococcidiopsis*

Despite the use of hot and cold desert strains of *Chroococcidiopsis* in ground-based simulations of space and Martian conditions [3], and in space in the frame of the ESA STONE experiments [4], their phylogenetic relationships are still unclear.
Thirteen strains of *Chroococcidiopsis* were selected from the Culture Collection of Microorganisms from Extreme Environments (CCMEE) as representatives of five desert areas, namely Middle East (Negev, Sinai), Central Asia (Gobi), North America (Sonora), South America (Chile) and Antarctica (Dry Valleys). The phylogenetic analysis were carried out by comparing the trees inferred from 16S rRNA gene sequences and the housekeeping gene *recA*. To generate the most accurate topology among the investigated *Chroococcidiopsis* strains, the phylogenetic analysis was carried including in the data set *Chroococcidiopsis* isolates and environmental sequences obtained from different environments and available from NCBI-GenBank. The phylogenetic analysis revealed that the investigated strains cluster into different groups.

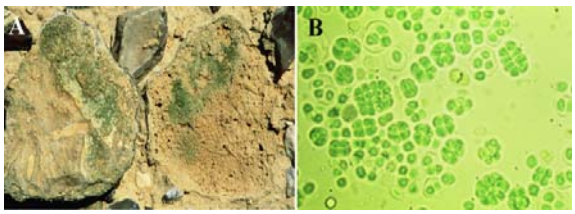

Figure 1. A: hypolithic growth in Negev desert, B. *Chroococcidiopsis* sp. (photos: E. Imre Friedmann).

3. Survival potential of desert strains of *Chroococcidiopsis*

Desert strains of *Chroococcidiopsis* isolated from Negev, Atacama and Dry Valleys were investigated for their capability to survive prolonged desiccation under laboratory conditions, high doses of ionizing radiation and simulated space and Martian conditions. It was speculated that their desiccation tolerance relays on the capability to avoid and repair otherwise lethal DNA damage [5]. Furthermore if shielded under 3 mm of sandstone dried cells of *Chroococcidiopsis* cells can survive the exposure to simulated space and Martian conditions as expected for 1,5 year permanence in space with a Mars like UV radiation [3]. Exposed dried cells of strain from coastal desert, Chile maintained the replication competency, protected the investigated subcellular components, and depending to the exposure conditions, avoided DNA damage or repaired the induced one upon rewetting [3].

4. DNA repair system in desert strains of *Chroococcidiopsis*

Indications of an efficient DNA repair system in desert strains of *Chroococcidiopsis* were given by the capability of actively growing cells to mend genomic fragmentation induced by ionizing radiation [1] and ability of rehydrated cells to repair DNA damage accumulated during the exposure of dried cells to an unattenuated Martian UV flux [6]. Unravelling the DNA repair system in desert strains of *Chroococcidiopsis* is a formidable challenge. Hence, taking advantage of desert strains of *Chroococcidiopsis* previously identified as suitable to genetic mutilation (Billi et al. 2000), two genetic systems were developed to i) visualize DNA repair protein in *Chroococcidiopsis* by using GFP-tagging, and ii) evaluate the mutation rate in *Chroococcidiopsis* after exposure to DNA damaging conditions.

5. Summary and Conclusions

Overall the outcome of the ongoing researches will contribute to validate *Chroococcidiopsis* as a well-defined and described photoautotrophic model for astrobiological research.

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