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Monitoring photosynthetic activity using *in vivo* chlorophyll *a* fluorescence in microalgae and cyanobacteria biofilms in the Nerja Cave (Malaga, Spain)

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Abstract: The characterization of the most common photosynthetic biofilms in the Nerja Cave by the continuous monitoring of the in vivo chlorophyll a (Chl *a*) fluorescence and the incorporation of the irradiance as a new environmental variable related to previous studies in the cave, have allowed us to improve our knowledge about the photosynthetic pattern of the biofilms of the cave. Effective quantum yield ($\Delta F/F_m'$) and relative electron transport rate (rETR) were determined during periods of the light, whereas the maximal quantum yield (F_v/F_m) was determined during dark periods. Increases in the photosynthetic yields and productivity in summer period were found related to the highest values of the environmental variables, such as relative humidity, air carbon dioxide concentration and air temperature. According to the irradiance, the studied biofilms had an optimal growth with cave lighting, considered low in comparison with similar studies, perhaps because they can grow mixotrophically too. Moreover, when the irradiance increased, both the $\Delta F/F_m'$ and the rETR decreased in springtime, suggesting photoinhibition of the photosynthetic yield in the biofilms within the cave, whereas in the summertime, the photosynthetic yield had a positive correlation with the irradiance, suggesting a decreased of the photoinhibition, possibly due to the increase of the environmental variables values which provokes an alleviate on the extent of photoinhibition.

Keywords: Biodeterioration, cyanobacteria, *in vivo* chlorophyll *a* fluorescence, microalgae, Nerja Cave

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INTRODUCTION

Cyanobacteria and microalgae biofilms can induce biodeterioration in natural and cultural heritage. Traditional techniques used to control photosynthetic biofilms damage in subterranean environments have been based on physical, mechanical, and chemical methods but most of them are considered risk factors for the conservation of the subterranean heritage (Mulec, 2009; Baquedano et al., 2019). Therefore, friendly environmental alternatives for combating the development of these biofilms are currently evolving towards the use of UV-C radiation (Borderie et al., 2015; Pfendler et al., 2018), hydrogen peroxide solution (Faimon et al., 2003; Trinh et al., 2003; Baquedano et al., 2019) or lighting sources that reduce photosynthetic activity (Roldán et al., 2006; Hsieh et al., 2013; Álvarez-Gómez et al., 2015). However, photoautotrophic biofilms can survive in hostile environments such as the caves, frequently characterized by low lighting and desiccation periods (Potts, 1999; Luttge et al., 2009; Behrendt et al., 2020). In fact, among different biological members, cyanobacteria and microalgae have been highly adaptive throughout many eons and can grow autotrophically, heterotrophically or mixotrophically.

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