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Effects of UVB radiation on the initial stages of growth of *Gigartina skottsbergii, Sarcothalia crispata* and *Mazzaella laminarioides* (Gigartinales, Rhodophyta)

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Abstract

The effects of UVB radiation on the growth of macroalgal thalli were evaluated using tetrasporophytic fronds of the Rhodophytes *Gigartina skottsbergii, Sarcothalia crispata* and *Mazzaella laminarioides.* The tetrasporophytic fronds were collected from nature and the tetrasporophyte sporelings grown in a temperature regulated chamber at 8 ± 2 °C with a 12L:12D (Light: Dark) photoperiod, Photosynthetically Active Radiation (PAR) of 55 μmol photons m^{-2} s^{-1} and seawater enriched with 20 mL L^{-1} of Provasoli medium. We exposed the thalli of these macroalgae to PAR (55 μmol photons m^{-2} s^{-1}) and three treatments using a combination of PAR with three different levels of UVB radiation (0.10, 0.15 and 0.23 W m^{-2} for *G. skottsbergii* and *S. crispata* and 0.02, 0.05 and 0.10 W m^{-2} for *M. laminarioides*) during a period of 71 days. Growth of thalli was quantified by measuring their length using digitized photographs of samples.

Important differences were detected in the growth of individuals cultured under the effects of UVB radiation, when compared to the control (i.e. plants exposed to PAR only). In the case of *G. skottsbergii* and *S. crispata* higher levels of UVB radiation resulted in slower growth of thalli. In nearly all measurements for the first two species, UVB radiation levels of 0.1 W m^{-2} induced differences in thallus growth, while for *M. laminarioides* levels of UVB radiation of 0.1 W m^{-2} were effective only after a prolonged period of exposure.

Differential effects of UVB radiation on *G. skottsbergii, S. crispata* and *M. laminarioides* could interfere with the natural populations of these economically important macroalgal species in southern Chile, where they occur under the annual influence of the Antarctic Ozone Hole and the general thinning of the ozone layer.

Introduction

One of the most recognized atmospheric changes during the last decade is the thinning of the stratospheric ozone layer (Kirchhoff et al., 1997). This phenomenon is particularly intense during the austral spring (September to November) in the Magellanic Region (53°S; 70.9°W), the southernmost tip of the American Continent. This results in increased levels of ultraviolet-B radiation (UVB: 280–320 nm) reaching the Earth's surface (Seckmeyer & McKenzie, 1992). UVB is known as the most biologically active type of UV radiation (Komhyr et al., 1989) and is considered harmful to living beings (Diffey, 1991).

Research on UVB radiation and terrestrial plants has demonstrated diverse effects, ranging from variations in leaf morphology to changes in processes such as growth, photosynthesis and flowering (Barnes et al., 1990; Teramura & Sullivan, 1991; Cuadra et al., 1997). Since UV radiation also penetrates the water column (Figueroa, 2002), marine organisms are exposed to its harmful effects, as well. In the intertidal zone, sessile organisms, such as macroalgae, are exposed to high intensities of solar radiation, especially during low tides

(Franklin & Forster, 1997). The negative effects of UVB radiation on algae result in an increase in the concentration of chlorophyll and carotenes (Grobe & Murphy, 1998) and the synthesis of UV screening compounds, such as mycosporines (Franklin et al., 2001; Huovinen et al., 2004). Negative effects are also evident in cellular development and the ultrastructure of the macroalgae (Poppe et al., 2003; Navarro, 2004), as well as in damage to nuclear DNA, principally at the level of nitrogenated bases (Buma et al., 2000; van de Poll et al., 2001).

Physiological processes, such as photosynthesis, are also affected by the action of UV radiation on macroalgae (Dring et al., 1996; Bischof et al., 1998). The photosynthetic rate is seriously affected as the result of variations in the concentration of photosynthetic pigments (Bischof et al., 2000; Yakovleva & Titlyanov, 2001), affecting the productive capacity of energetic molecules like ATP, or by serious damage at the level of electron transport of Photosystem II (Renger et al., 1989; Nedunchezhian & Kulandaivelu, 1991; Kolli et al., 1998). On the other hand, studies conducted in high latitudes demonstrate that UV light can also cause decreased primary productivity, thereby changing the composition of autotrophic communities (Worrest, 1983; Vincent & Roy, 1993; Bischof et al., 1998).

Some researchers have shown that UV radiation affects the absorption of Photosynthetic Active Radiation (PAR) in phytoplankton, due to a decrease in the content of photosynthetic pigments (Montecinos & Pizarro, 1995). UV radiation has also been shown to interfere in the development of chloroplasts and to decrease photosynthetic rate by photoinhibition, in various macroalgal species (Larkum & Wood, 1993; Maegawa et al., 1993; Meindl & Lütz, 1996; Poppe et al., 2003). This in turn affects cellular expansion, and growth, as has been observed in *Ulva expansa* (Grobe & Murphy, 1997, 1998).

In Chile, studies regarding the effects of UVB radiation on algae are scarce, and they have focused on aspects such as phytoplankton acclimation to UV radiation (Montecinos & Pizarro, 1995), the ability of apical segments, cystocarps and thallus fragments of *Gracilaria chilensis* to acclimate to UV radiation (Molina & Montecinos, 1996) and the mycosporine content in red algae of southern Chile (Huovinen et al., 2004). Here, we evaluate the effects of UVB radiation on thallus growth of *Gigartina skottsbergii* Setchell & Gardner, *Sarcothalia crispata* (Bory) Leister and *Mazzaella laminarioides* (Bory) Fredericq under laboratory conditions. All of these carragenophytes are economically important to the Magellanic Region.

Materials and methods

Biological material

Fertile tetrasporophytic fronds of *Gigartina skottsbergii, Mazzaella laminarioides* and *Sarcothalia crispata* were collected from the intertidal and subtidal zone in the Strait of Magellan and transported in glass containers with marine water to the Marine Biology Laboratory of the Department of Natural Sciences and Resources, Faculty of Science, University of Magallanes, Chile.

Visible and UVB radiation source

Three levels of exposure to UVB were used in laboratory experiments (0.1, 0.15 and 0.23 W m^{-2} for *G. skottsbergii* and *S. crispata* and 0.02, 0.05 and 0.10 W m^{-2} for *M. laminarioides*), and were nominated as UVB1, UVB2 and UVB3 respectively (Table 1), which were supplied by three artificial UVB tubes (TL 20 W/12RS, Philips) with an output at 312 nm. The levels were obtained by adjusting the height of the UVB tubes above the dishes. UVC light was filtered out with cellulose diacetate foil (0.075 mm thick), which allowed 0% transmission below 280 nm. The filters were replaced after 85 h of use to avoid degradation.

For the control and all UVB treatments, PAR tubes (Philips TLT 20 W/54 daylight fluorescent) were used. PAR was kept low and constant during the entire experimental period at 55 μmol photons m^{-2} s^{-1}.

Experimental treatment and culture condition

Fragments of tetrasporophytic fronds of each of the three species (*G. skottsbergii, M. laminarioides* and *S. crispata*) were carefully washed with tap water and distilled water to eliminate epiphytes and remnants of organic matter. Sporulation, was induced in test tubes containing 50 mL of seawater; test tubes were periodically shaken to avoid spore settlement. For each species, 12 glass slides were inoculated.

Once spores settled on the glass slides, the gametophytes germlings were divided into four groups (3 slides per group) for each species. Slides from the same treatment group were placed in plastic containers with filtered and sterilized seawater and enriched