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# Effect of UV-B radiations on the pigments of two Antarctic lichens of Schirmacher Oasis, East Antarctica

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**Abstract**: Antarctic plants experience UV-B stress and for their survival they have been showing various adaptive strategies. The first line of defence is to screen UV-B radiation before it reaches the cell, then to minimize damage within the cells through other protective strategies, and finally to repair damage once it has occurred. A fifteen days experiment was designed to study lichen: *Dermatocarpon* sp. and *Acarospora gwynnii* under natural UV and below UV filter frames in the Indian Antarctic Station *Maitri* region of Schirmacher Oasis, East Antarctica. Changes in UV absorbing compounds, total phenolics, total carotenoids and chlorophyll content were studied. The change in total phenolics and total carotenoid content was significant in both *Dermatocarpon* sp. and *A. gwynnii* indicating that the increase in UV absorbing compounds, total phenolics and total carotenoid content act as a protective mechanism against the deleterious effect of UV-B radiations, whereas the change in chlorophyll content was not significant in both lichen species.

Key words: Antarctica, UV-B radiation, lichens, carotenoids, phenolics, chlorophyll.

## Introduction

Antarctica is a place well known for its adverse conditions: low temperature, low water availability, strong winds and high incidence of solar, especially the UV radiation, altogether limiting plant and animal life. Absorption of UV-B radiation by plants can damage and disrupt key biological molecules. Depletion of stratospheric ozone, resulting from anthropogenic, atmospheric pollution, has led to increase ultraviolet (UV) radiation at the Earth's surface, as well as a spectral shift to the more biologically damaging shorter wavelengths (Frederick and Snell 1988). The decrease in ozone has been most pronounced and consistent over Antarctica with record levels of austral ozone depletion in the last decade (Bodeker *et al.* 2001; McKenzie *et al.* 2003; Robinson *et al.* 2003; NASA 2006). As a consequence, Antarctica now experiences unseasonably high UV-B radiation through much of the

spring, caused by the combined effects of the "ozone hole" and the approach of the natural annual radiation peak, the summer solstice (Frederick and Snell 1988; Roy *et al.* 1994). As a consequence of these severe conditions, the Antarctic flora is almost entirely cryptogamic, only two vascular species do occur there, both are restricted to the relatively mild Antarctic Peninsula. Lower plants are more likely susceptible to UV-B damage because of their simple structure, with most lacking differentiation and the protective cuticle or epidermal layer of higher plants. Combined with the physiologically stressful effects of repeated freeze/thaw cycles, an intermittent water supply and limiting nutrients, polar flora is likely to be sensitive to the additional stress imposed by elevated UV-B radiation (Robinson *et al.* 2003; Wasley *et al.* 2006 a, b). The survival of Antarctic plants under ozone depletion depends on their ability to acclimate to increasing UV-B radiation by employing photo protective mechanisms to avoid or repair UV-B damage (Jansen *et al.* 1998). UV-B absorbing pigments are widespread across the plant kingdom, due to their ability to absorb biologically damaging UV-B radiation while transmitting essential photosynthetically active radiation (Cockell and Knowland 1999). UV-absorbing compounds play a very important role in plant kingdom and one of the many roles of these compounds appear protective to organisms from harmful effects of UV-B radiation by means of their direct absorption of these wavelengths. However, recent evidence suggests that some of the phenolic compounds may contribute to the decrease in active oxygen species by acting as antioxidants (Husain *et al.* 1987; Foyer *et al.* 1994; Markham *et al*. 1998; Olsson *et al.* 1998; Ryan *et al*. 2002). In this paper we have studied two Antarctic lichens: *Dermatocarpon* sp. and *Acarospora gwynnii*, under natural environmental conditions and under UV protecting cover. The main aim of the study was to examine the changes in UV absorbing compounds, total phenolics, total chlorophyll content and carotenoids due to UV radiation.

## Material and methods

**Study site and experimental set-up**. — The Schirmacher Oasis region of east Antarctica (70°45'01.65" S, 11°43'01.45" E) of a series of low-lying peninsulas and islands, which become partially ice-free during the summer melt period. Screening treatments were established near the Priyadarshini Lake and around Indian Antarctic Station *Maitri*. These sites were chosen because the selected plant species grow naturally and have greater exposure to both sunlight and wind.

The experimental boxes were designed as 12×12 cm iron frames, 1cm high, covered with 12×12 cm of UV holding Mylar sheet attenuating 98% of total UV-B radiation (Fig. 1). The sides of the metal frame box contained mesh for the proper aeration and maintaining the same temperature inside and outside the metal frame box. These UV filter frames placed over *Dermatocarpon* sp. and *Acarospora gwynnii* under natural conditions other than UV-B radiation *i.e.*, light, temperature, air ventila-


Fig. 1. UV filter frame used for controlled experimental set up.

tion, served as UV unexposed for continuous study of the plant specimen over fifteen days of duration. A simultaneous study in UV exposed condition was carried over the plants without UV filter frame. Samples were collected daily from both the specified conditions and were analyzed for the change in UV absorbing compounds, phenolics, total chlorophyll content and carotenoids. The study was performed in austral summer months, from December 2008 to January 2009.

**Extraction of pigments**. — For chlorophyll content estimation 100 mg of the plant sample was crushed in 5 ml of 80% acetone solution (80 ml acetone finally make up to 100 ml with distilled water) at 4°C and spin in centrifuge at 10,000 rpm for 10 minutes. Supernatant was taken and optical density (O.D) was measured at 663 nm, 645 nm, 510 nm for chl. a, chl. b and carotenoids respectively (Arnon 1949).

For UV absorbing compounds 5 ml of acidified methanol (MeOH : HCl : $H_2O$ 90 : 1 : 1) was taken and 100 mg of plant sample was heated at 60°C and stirred for 10 minutes in 25 ml flask. It was cooled at room temperature for 15 minutes and filtered through Whatman paper no. 5 and absorbance was recorded at 300 nm (Ruhland and Day 2001).

For total phenolics study the 100 mg of plant sample was homogenized (10% w/v) in acidified methanol (50% methanol 0.05% HCl, pH 3.5). Homogenate allowed to settle for 15 h in dark at 0–4°C and filtered through Whatman paper no. 5 and absorbance recorded at 280 nm (Pirie and Mullins 1976).

**Statistical analyses**. — For statistical analyses of the data graph pad was used. The chlorophyll and pigment data of the UV natural and UV-filter experiment, two way ANOVA was used. Treatment effects were considered significant at the $P < 0.05$ level.

Table 1

Concentration of chl. a and chl. b under UV exposed condition at *Maitri*, East Antarctica

| Plant | Chl. a mg/gm fresh wt (mean value) | | | Chl. b mg/gm fresh wt (mean value) | | |
|---|---|---|---|---|---|---|
| | Day 1 | Day 7 | Day 15 | Day 1 | Day 7 | Day 15 |
| *Dermatocarpon* sp. | 0.151± 0.002 | 0.140± 0.001 | 0.129± 0.002 | 0.064± 0.001 | 0.238± 0.002 | 0.043± 0.002 |
| *A. gwynnii* | 0.136± 0.003 | 0.130± 0.002 | 0.120± 0.005 | 0.041± 0.002 | 0.035± 0.002 | 0.022± 0.005 |

Table 2

Concentration of chl. a and chl. b under UV Filter frame condition at *Maitri*, East Antarctica

| Plant | Chl. a mg/gm fresh wt (mean value) | | | Chl. b mg/gm fresh wt (mean value) | | |
|---|---|---|---|---|---|---|
| | Day 1 | Day 7 | Day 15 | Day 1 | Day 7 | Day 15 |
| *Dermatocarpon* sp. | 0.151± 0.003 | 0.155± 0.002 | 0.166± 0.002 | 0.063± 0.001 | 0.069± 0.002 | 0.077± 0.005 |
| *A. gwynnii* | 0.135± 0.001 | 0.140± 0.002 | 0.146± 0.005 | 0.041± 0.002 | 0.048± 0.002 | 0.056± 0.001 |

## Results

Lichen *Dermatocarpon* sp. and *Acarospora gwynnii* were studied for fifteen days under UV filter frames and without filter frames to monitor the changes in UV absorbing compounds, total phenolics, total carotenoids and chl. a, chl. b and total chlorophyll content. The change in UV absorbing compounds, total phenolics and carotenoids was significant in both *Dermatocarpon* sp. and *A. gwynnii*. The change in the UV absorbing compound was somewhat more significant in *Dermatocarpon* sp. ($P < 0.0312$) than in *A. gwynnii* ($P < 0.0369$). The change in phenolic compounds was more significant in *Dermatocarpon* sp. ($P < 0.0276$) than in *A. gwynnii* ($P < 0.0369$). Change in carotenoid content under the effect of UV-B stress was more significant in *A. gwynnii* ($P < 0.0255$) than in *Dermatocarpon* sp. ($P < 0.0723$). The change in chlorophyll content was not significant in both the lichen plants which clearly indicated that the increase in UV absorbing compounds, total phenolics and total carotenoid content act as a protective mechanism against the harmful effect of UV-B radiations. The results obtained are summarized in Table 1 and Table 2. Results are also graphically represented in Figs 2–7.

## Discussion

In present study we found that the chlorophyll content experienced some changes when studied under UV filter frames and natural UV conditions but the change was not very significant. Changes in chlorophyll have been observed in

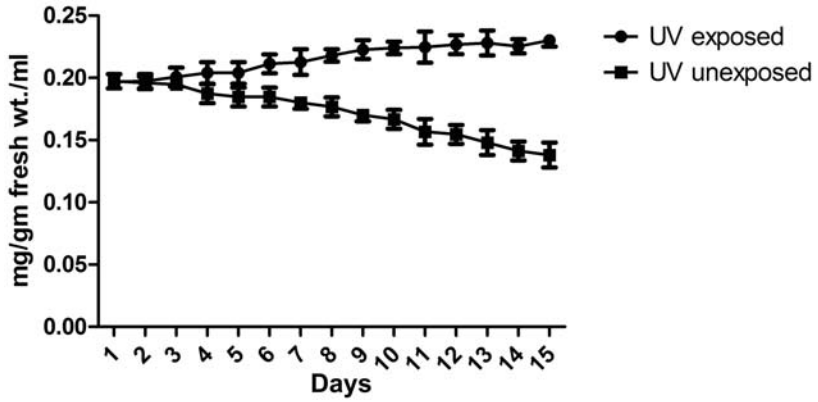


Fig. 2. Change in UV absorbing compounds under UV exposed and unexposed conditions in *Dermatocarpon* sp. (P <0.0312).

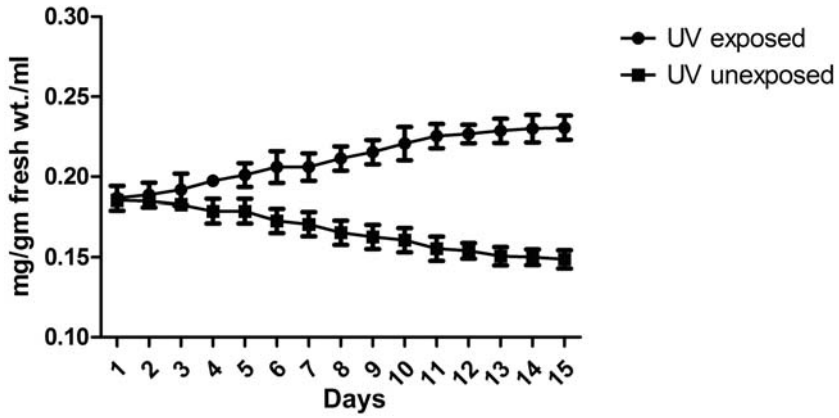


Fig. 3. Change in total phenolic compounds under UV exposed and unexposed conditions in *Dermatocarpon* sp. (P <0.0276).

some species but are not a consistent response to natural variations in UV-B exposure, although they have previously been observed in Arctic bryophytes in response to enhanced UV-B radiation (Gehrke 1999; Searles *et al.* 2001; Caldwell *et al.* 2003). No change in chlorophyll concentration was observed as a result of seasonal changes in UV-B radiation in either the South American *Sphagnum magellanicum* (Searles *et al.* 2002) or two Antarctic bryophytes studied by Newsham *et al.* (2002).

Carotenoid synthesis is known to be induced by exposure to UV-B radiation (Cockell and Knowland 1999). The data from the present study indicate that carotenoid concentration positively associated with increase in UV-B radiation arising from ozone depletion, corroborate the data of Xiong and Day (2001), who showed increased concentration of these pigments in foliage of *C. quitensis* and *D. antarctica* plants exposed to near-ambient solar UV-B, compared with plants exposed to reduced UV-B. Similarly, increased carotenoid concentrations have been

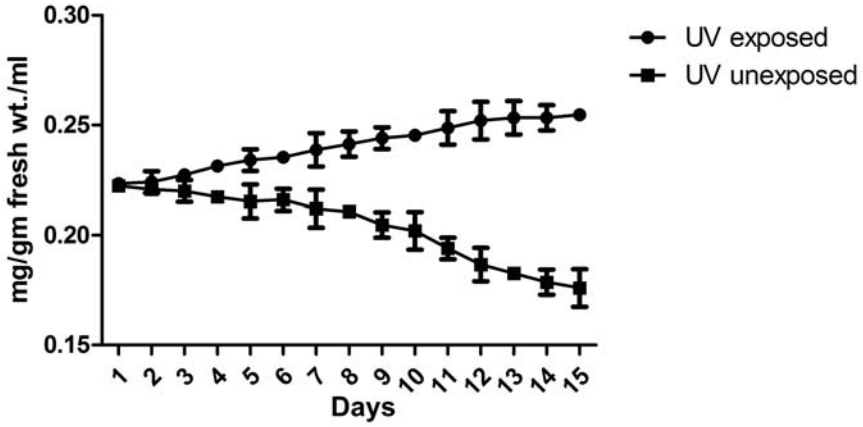


Fig. 4. Change in total carotenoids under UV exposed and unexposed conditions in *Dermatocarpon* sp. (P <0.0723).

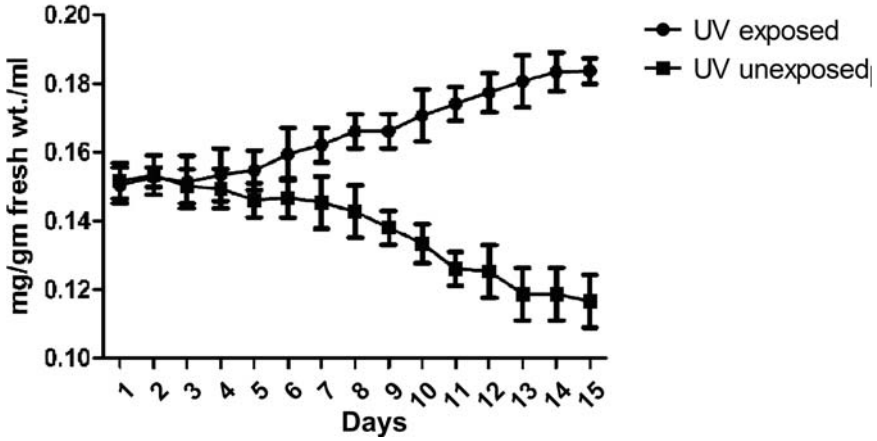


Fig. 5. Change in UV absorbing compounds under UV exposed and unexposed conditions in *A. gwynnii* (P <0.0369).

found in foliage of the bryophytes *Cephaloziella exiliflora* and *Sanionia uncinata* at Rothera Point during periods of ozone depletion (Newsham *et al.* 2002).

UV-B absorbing pigments are widespread across the plant kingdom, due to their ability to absorb biologically damaging UV-B radiation while transmitting essential photosynthetically active radiation (Cockell and Knowland 1999). In the present study we found that the concentration of UV-B absorbing compounds increased significantly when studied under natural UV-B condition as compared to those studied under UV-B filter screens. Antarctic field experiments have shown increased concentrations of UV-B screening pigments in foliage of the pearlwort *Colobanthus quitensis* and the grass *Deschampsia antarctica* exposed for four months to near-ambient solar UV-B radiation under plastic screens on the western Antarctic Peninsula, compared with plants exposed to reduced UV-B radiation (Ruhland and Day

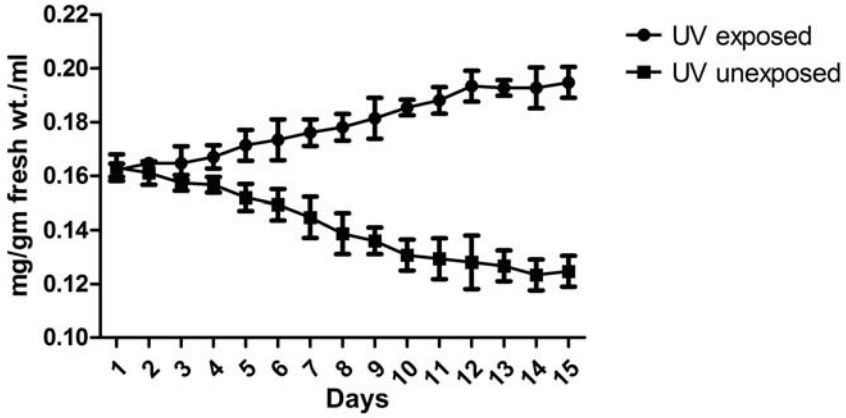


Fig. 6. Change in total phenolic compounds under UV exposed and unexposed conditions in *A. gwynnii* (P <0.0369).

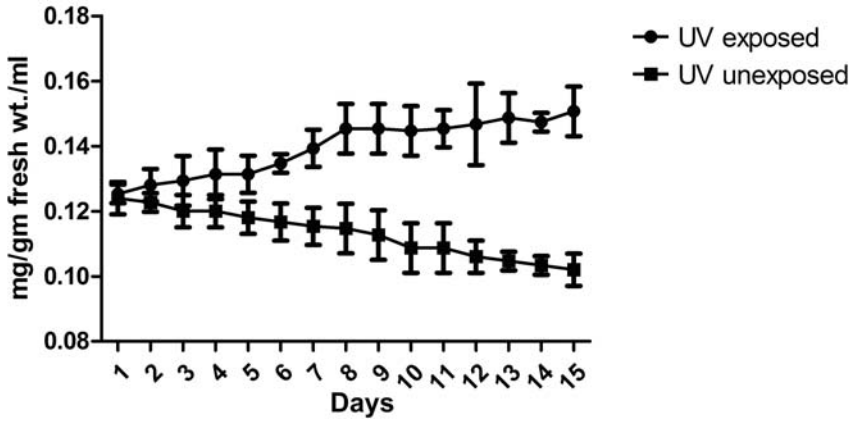


Fig. 7. Change in total carotenoids under UV exposed and unexposed conditions in *A. gwynnii* (P <0.0255).

2000; Xiong and Day 2001). The widespread accumulation of UV-B screening pigments in plant tissues in response to UV-B radiation owes at least in part to flavonoid synthesis, caused by the induction of genes encoding chalcone synthase, a key enzyme in the flavonoid biosynthesis pathway (Jordan *et al.* 1994).

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