

## Species-specific ecophysiological features of Antarctic mosses during desiccation: A study of *Brachythecium austro-glareosum* and *Bryum pseudotriquetrum*

Alla Orekhova

*Department of Experimental Biology, Laboratory of Photosynthetic Processes, Faculty of Science, Masaryk University, University Campus – Bohunice, Kamenice 5, 625 00 Brno, Czech Republic*

**Key words:** Antarctica, dehydration, rehydration, mosses, reflectance, chlorophyll fluorescence

### INTRODUCTION

Mosses are considered highly resistant against desiccation because they maintain photosynthetic activity even at severe dehydration. In our study, we focused on the dehydration-induced responses of primary photosynthetic processes and spectral reflectance in two moss species from the James Ross Island, Antarctica. Although both of the studied mosses on the James Ross Island occur in a similar habitat, we hypothesized that their tolerance to drying, though high, would be species-specific. With regard to the anatomic-morphological characteristics of each species, we assumed that *Brachythecium austro-glareosum* would show lower resistance of the photosynthetic processes to the strong degree of drying than *Bryum pseudotriquetrum*. Last but not least we analyzed the extent of protective quenching mechanism activated in the two species by dehydration.

### MATERIALS AND METHODS

Samples of *Brachythecium austro-glareosum* and *Bryum pseudotriquetrum* were collected from James Ross Island (Antarctica). Collection site was located on N-facing slope (63° 48' 12'' S, 57° 51' 02'' W) and fed by several snowfields located on northern foothill of the Berry Hill mesa.

Restoration of photosynthetic processes upon rehydration was studied by chlorophyll fluorescence (ChlF). Activation of primary photosynthetic processes after rehydration was evaluated by a slow Kautsky kinetics measurements with quenching mechanisms analysis. For desiccation experiments, the moss samples were handled as follows. During the desiccation, the change in water content of each sample was determined gravimetrically by a Mettler AE 100 scale (Germany). During the dehydration from fully wet to dry state, changes in the water potential (WP) of moss clusters were measured as well. Finally, the relation between WP and RWC was evaluated for particular moss species. During desiccation from fully state, the following ChlF parameters ( $\Phi_{PSII}$ ,  $F_S$ ) were measured repeatedly. For the purpose, a PAM-2000 fluorometer (Walz, Germany) with a custom-programmed measuring routine was used. Light response curves of apparent electron transport rate (ETR) were measured on samples of mosses, which had been maintained fully hydrated for at least 24 h before experiment. Then, the curves were measured by a modulated fluorometer PAM 2500 (Walz, Germany) using a standard protocol preprogrammed in the instrument during progressive drying at laboratory temperature. Reflectance spectra were measured within the range of 380–800 nm using a

PolyPen RP 400 UV VIS spectrophotometer (Photon Systems Instruments, Brno, Czech Republic). Moss samples were measured repeatedly during gradual dehydration from fully wet to dry state. From spectral reflectance data, the photochemical reflectance index (PRI) and Normalized Difference Vegetation Index (NDVI) and several others (CARI, MCARI, G, CI, CCRI, Pq) were calculated.

## RESULTS

Rehydration response curves showed the time required for complete restoration of primary photosynthetic processes in PSII. For both species, 32 h was the time to reach maximum values of  $F_V/F_M$  and  $\Phi_{PSII}$ . Rehydration-response courses of NPQ were found species-specific. For *B. austro-glareosum*, NPQ showed polyphasic and complex curve with local minimum found in the interval of 5–9 h of rehydration, and two maxima (45 min, and 27 h). The NPQ minimum corresponded to the time at which  $F_V/F_M$  and  $\Phi_{PSII}$  exhibited the fastest increase, and the local maximum of steady-state chlorophyll fluorescence ( $F_S$ ).

Within the RWC range of 40–100%,  $\Phi_{PSII}$  showed no change with dehydration in both species. With pronounced desiccation (RWC decrease from 40 to 0 %, i.e. from water potential of 8.0 MPa), a rapid decline to full inhibition of primary photochemical processes of photosynthesis ( $\Phi_{PSII} = 0$ ) was apparent. The decline was comparable in both species, however *B. pseudotriquetrum* showed higher resistance to dehydration since the half of maximum value was found at lower RWC than in *B. austro-glareosum*. During gradual dehydration,  $F_S$  declined in a polyphasic manner and showed species-specific differences. Rapid dehydration-induced decline started at different RWCs. The starting point was found at higher RWC in *B. austro-glareosum* (40%) than *B. pseudotriquetrum* (30% RWC).

ETR responded to gradual desiccation differently in both species. ETR increase was found during the initial phase of dehydration (RWC decrease from 100 to 20%) in *B. austro-glareosum* while no such response was apparent in *B. pseudotriquetrum*. In the latter species, ETR in response to PAR did not change within the range of RWC (decrease from 100 to 40%). The experimental species differed in the alpha parameter, which represents the initial slope of the curve in low light and denotes effectivity of photosynthetic electron transport per PAR unit.

Spectral reflectance curves as well as indices showed different sensitivity to dehydration. NDVI, G, and MCARI declined with a decrease in RWC. In spite of similar trends in dehydration-response curves (NDVI, GI, MCARI), species-specific differences were found for values. PRI dehydration-response curve showed different shape for *B. austro-glareosum*, and *B. pseudotriquetrum*. Phaeophytization index (Pq) increased with RWC decrease. The relationship was found polyphasic in *B. austro-glareosum* but linear in *B. pseudotriquetrum*. Carotenoid index (CARI), the carotenoid to chlorophyll ratio (CCRI), as well as the red edge chlorophyll index ( $CI_{red-edge}$ ) decreased and increased in dry state of *B. austro-glareosum* and *B. pseudotriquetrum*, respectively.

## DISCUSSION

Rehydration time was comparable to other moss species, however shorter times are reported from ecophysiological studies for several moss species. Moreover, species-specific differences exist in the re-wetting time that might be attributed to the length of the hydrated activity period before desiccation. Since the two Antarctic mosses used in our study undergo rather rapid desiccation in the field (thank to co-action of wind speed

and temperature), we may attribute the time of rehydration found in our study (32 h) to the fact that the two species grow in polar deserts and have an ecophysiological strategy of inducible desiccation tolerance related to the site-dependent rapidity of desiccation.  $F_v/F_M$  and  $\Phi_{PSII}$  were well related which means that at any thallus hydration and the stage of cell function restoration, both potential and actual photosynthetic processes in PS II were well coupled.

The change in  $F_S$  decline rate found during desiccation at the RWCs of 50% (*B. austro-glareosum*) and 20% (*B. pseudotriquetrum*) could be attributed to the early stage of dehydration and its effects on primary photosynthetic processes. In both species, the decline of  $F_S$  at the RWCs below 40% might be attributed to a gradual loss of water from the cells and a consequent decrease in the ChlF signal.

The above-specified mechanisms are involved in protection of PSII during desiccation and demonstrated as  $q_N$  (NPQ) increase. Our data supports such interpretation since  $q_N$  tended to increase (exponentially or following a S-curve, data not shown) at the RWCs below 50 (*B. austro-glareosum*) and 15–30% (*B. pseudotriquetrum*).

Rapid light-response curves showed a strong limitation of photosynthetic electron transport (ETR) at the RWC below 20%. Spectral reflectance indices responded to desiccation similarly in the two species (NDVI, MCARI, G), however, species-specific differences was found in photochemical reflectance index (PRI). These results suggest that both species are desiccation tolerant and well adapted to harsh Antarctic environments. However, *B. pseudotriquetrum* is more resistant in severe dehydration (RWC below 20%) than *B. austro-glareosum*.