

Increased temperature benefits growth and photosynthetic performance of the sea ice diatom *Nitzschia cf. neglecta* isolated from Lake Saroma, Hokkaido, Japan

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Lake Saroma, connected to the Sea of Okhotsk, is located at the lowest latitude where seasonal sea ice can develop (Kudoh et al. 1997). During ice melt in spring, ice algal communities are exposed to higher temperatures and irradiance levels in surface waters when algal cells are released into the changeable light climates of coastal waters (Rajanaahally et al. 2014). Despite the overwhelming dominance of diatom blooms during ice melt, how they have acclimated to these extreme environmental conditions is largely unknown. Emerging evidence indicates that ice diatoms may be plastic organisms that possess effective photoacclimative strategies (Young et al. 2015). Since Lake Saroma is only seasonally covered by sea ice, variation in temperatures can be very large throughout the year. Therefore, the first aim of this study was to test their tolerance to a higher temperature. Cells of the pennate diatom *Nitzschia cf. neglecta*, isolated from sea ice from Lake Saroma, were grown under irradiance levels of 30 and 100 $\mu\text{mol photons m}^{-2} \text{s}^{-1}$, and temperatures of 2 and 10 °C. Acclimated cells in the exponential phase were exposed to 450 $\mu\text{mol photons m}^{-2} \text{s}^{-1}$ to simulate high light during ice melt, in order to investigate plasticity of their photosynthetic apparatus. These include photochemical efficiencies of PSII, cellular pigment composition, and the transcription levels of two key genes involved in photosynthesis, *rbcL* and *psbA*, which encodes the large subunit of RuBisCO (Ribulose-1, 5-Bisphosphate Carboxylase/Oxygenase) and D1 protein of Photosystem II, respectively. The strain not only exhibited a high temperature tolerance of up to 10 °C which is much higher than that of the bottom-sea ice environment, but also grew faster at that temperature. The maximum photochemical efficiency, F_v/F_m , were above 0.65 under all culturing conditions, and was higher at 10 °C and in LL grown cells. This indicates that the photosynthetic apparatus were healthier under such conditions. High saturation irradiance levels in the rapid light curve implied weak adaptation to shade. Cellular contents of fucoxanthin and the two chlorophylls, Chl *a* and *c* were higher in LL than in HL, and the extent of difference was similar for each temperature. The ratios of fucoxanthin and Chl *c* to Chl *a* in this study were almost identical under the four culturing conditions. Furthermore, the pigment ratios remained almost steady during the exposure and the dark recovery. We suggest that these ratios could be rather conservative even under changing light conditions in this species. The immediate decrease in all pigment content upon exposure, as well as a higher cellular content of diatoxanthin at the lower temperature, indicates consistency in the acclimation of photosynthesis to low temperature and high light. The diadinoxanthin-diatoxanthin cycle was demonstrated to be the main photoprotective strategy. It is difficult to determine whether a fast regulation of PSII repair cycle was involved in the photoprotective strategies from the *psbA* transcription data. Interestingly, the lower photoprotective efficiency at 2 °C might have limited adverse effect on carbon fixation, since no significant decrease in *rbcL* transcription levels has been found during the exposure treatment at 2 °C. We suggest that the regulation through *psbA* and *rbcL* at the transcription level might have played a minor role in the response to high light conditions. We conclude that higher temperatures favour the survival and prevalence of this species during springtime ice melt in Lake Saroma capitalising on its effective photoprotection capability. The results provide us a better understanding of algal survival in highly changeable coastal water environments subject to seasonal sea ice.

References

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