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Gene expression profile of marine *Chlorella* strains from different latitudes: stress and recovery under elevated temperatures

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Abstract

Global warming, as a consequence of climate change, poses a critical threat to marine life, including algae. Studies on algal response at the molecular level to temperature stress have been significantly improved by advances in omics technologies. Algae are known to employ various strategies in response to heat stress. For example, algae regulate starch synthesis to provide energy for the cell or rebuild the damaged subunits of photosystems to regain photosynthetic activity. The aim of the present study is to examine the expression of selected photosynthesis-related genes of marine *Chlorella* originating from different latitudes, in response to heat stress and during the recovery period. In this study, marine *Chlorella* strains from the Antarctic, temperate region, and the tropics were grown at their ambient and stress-inducing temperatures. The maximum quantum efficiency (F_v/F_m) photosynthetic parameter was used to assess their stress levels. When subjected to heat stress, the F_v/F_m began to decline and when it reached ~ 0.2, the cultures were transferred to their respective ambient temperature for recovery. Total RNA was isolated from these cultures at F_v/F_m ~ 0.4, 0.2, and when it regained 0.4 during recovery. The expression of four genes including *psbA*, *psaB*, *psbC*, and *rbcL* was analyzed using RT-PCR. The housekeeping gene, histone subunit three (H3) was used for data normalization. Studying the genes involved in the adaptation mechanisms would enhance our knowledge on algal adaptation pathways and pave the way for genetic engineers to develop more tolerant strains.

Keywords Abiotic stress · Photosystem · Photosynthesis · Stress adaptation

Introduction

Global climate change is documented as one of the most serious environmental matters facing the Earth. An average rise of 4 to 5 °C is anticipated by the end of the century based on the report from the Intergovernmental Panel on Climate Change (IPCC) (Stocker et al. 2014). In addition, the severity, duration, and frequency of heatwaves, with unusually high temperatures are also increasing (Robinson 2001; Tripathi et al. 2016). It has been presented that climate variations are altering the base of the food web and consequently the food chain (Smith et al. 2008; Montes-Hugo et al. 2009). On a global scale, species respond to thermal stress with distributional range shifts and phenological alternations that often result in regional extinction (Jueterbock et al. 2014). Algae are omnipresent organisms that contribute to about half of the total primary production at the base of food chains (Behrenfeld et al. 2001; Beardall and Raven 2004; Chapman 2013; Falkowski and Raven 2013). Temperature plays a critical role in growth (Raven and Geider 1988; Singh and Singh 2015) and photosynthesis (Davison 1991; Huner et al. 1993), through changes in the stability of biomolecules and the rates of biochemical and physiological processes (Fujimoto et al. 1994). Fundamentally, optimal temperature increases growth rate, while temperatures beyond the optimal are lethal (Ras et al. 2013).

Algae photosynthesis is recognized as one of the most heat-sensitive processes and it can be entirely suppressed by high temperature earlier than other traits of the stress response are detected (Berry and Bjorkman 1980). Environmental stressors

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