INCREASED TEMPERATURE ENHANCES PHOTOSYNTHESIS AND INHIBITS COPPER UPTAKE IN *E. siliculosus*

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Introduction

Brown seaweeds are major primary producers and important bio-engineers in cold-temperate coastal waters; providing habitat, food and shelter for a diversity of associated organisms; (Sáez et al., 2015). Copper is an essential micronutrient, required as a co-factor in certain proteins and enzymes such as plastocyanin, amine oxidase, cytochrome *c* oxidase (Connan and Stengel, 2011b). At elevated concentrations, Cu can become toxic and have detrimental effects on seaweed metabolism and physiology; for example, by inducing oxidative stress, inhibiting photosynthesis, disrupting development and, eventually, causing cell death (Sáez et al., 2015). Current knowledge about responses to Cu stress are derived from single factor exposure experiments, although it is known that seaweeds are exposed to multiple stressors in their natural environment (Sáez et al., 2015a). The potential consequences of interactions between metals and other abiotic stressors, for seaweed ecology are poorly understood. In this study we assessed the effects of temperature on the physiology and bioaccumulation of Cu in the filamentous brown algae *Ectocarpus siliculosus,* which has emerged as a model organism for studying various aspects if the biology of brown algae (Cock, Coelho, Brownlee, & Taylor, 2010).

Methods

The *E. siliculosus* strain Es524 (CCAP 1310/333) used in this study, has previously shown tolerance to Cu excess (Roncarati et al., 2015; Sáez et al., 2015a, b). Two hundred 200 mg of algae were exposed in triplicates to a range of Cu treatments: control (no added Cu), 0.8, 1.6, and 3.2 µM of nominal Cu for 6 d at 15 and 25°C. Chlorophyll *a* fluorescence parameters were measured at the end of the period of Cu exposure, using a mini-PAM Photosynthesis Yield Analyzer (Walz, Germany). Additionally, the total and intracellular accumulation of Cu were determined by inductively coupled plasma-mass spectrometry (ICP-MS) (Thermo Scientific, X Series 2) following the methodology described in Roncarati et al. (2015).

Results

After 6 d exposed to Cu excess, samples growing at 15°C had significantly lower photosynthetic efficiency, estimated by changes in Fv/Fm (One-way ANOVA, $p<0.05$) (Fig. 1a) and the initial slope of ETR vs. irradiance function "αETR", an estimator of photosynthetic efficiency (data not shown), if compared with algae growing at 25°C. Intracellular Cu accumulation displayed a similar result at highest concentrations (1.6 and 3.2 µM) as well as total accumulation at 3.2 µM treatment (Fig. 1b).

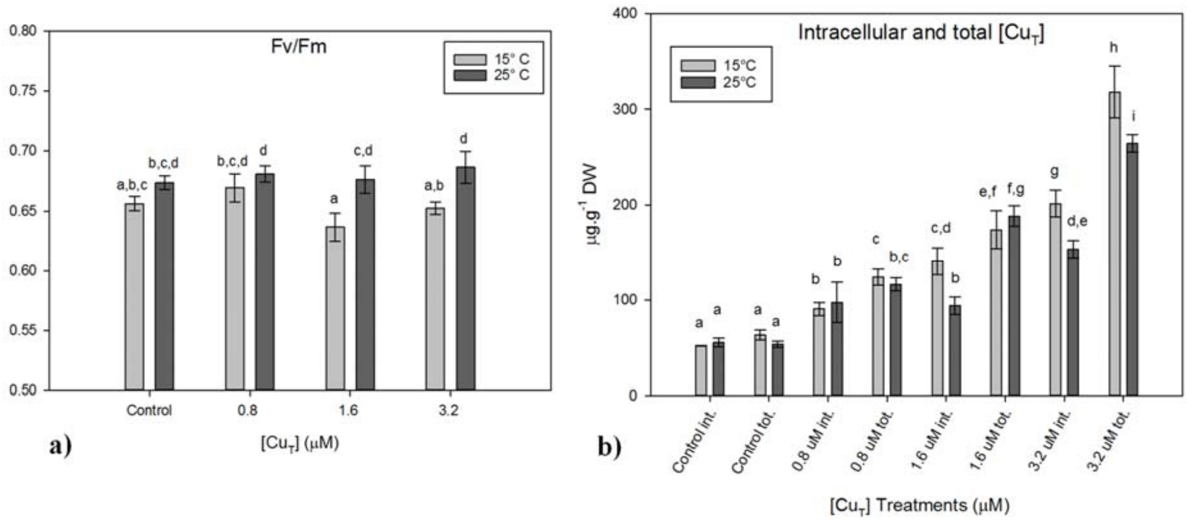

Figure 1. Maximum quantum yield (Fv/Fm) a) and intracellular and total Cu accumulation b) after 6 days of Cu exposure at different temperatures.

Conclusion

In this study we provide evidence that a rise in temperature enhances the photosynthetic efficiency and the detoxifying rates in *E. siliculosus* exposed to Cu excess. This is probably due to more efficient damage repair of the photosynthetic apparatus (Rautenberger et al., 2015), and/or changes in the biochemistry that affect the transport rates of Cu across the cell membranes. Further research at biochemical and molecular level is still needed to understand the mechanism underlying the interaction between Cu and temperature.

References

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