Solar UV Radiation Drives CO_2 Fixation in Marine Phytoplankton: A Double-Edged Sword[1]

Kunshan Gao*, Yaping Wu, Gang Li, Hongyan Wu, Virginia E. Villafañe, and E. Walter Helbling

Marine Biology Institute, Shantou University, Shantou, Guangdong 515063, China (K.G., Y.W., G.L., H.W.); State Key Laboratory of Marine Environmental Science, Xiamen University, Xiamen 361005, China (K.G.); State Key Laboratory of Freshwater Ecology and Biotechnology, Institute of Hydrobiology, Chinese Academy of Sciences, Wuhan, Hubei 430072, China (K.G.); and Estación de Fotobiología Playa Unión and Consejo Nacional de Investigaciones Científicas y Técnicas, 9103 Rawson, Chubut, Argentina (V.E.V., E.W.H.)

Photosynthesis by phytoplankton cells in aquatic environments contributes to more than 40% of the global primary production (Behrenfeld et al., 2006). Within the euphotic zone (down to 1% of surface photosynthetically active radiation [PAR]), cells are exposed not only to PAR (400–700 nm) but also to UV radiation (UVR; 280–400 nm) that can penetrate to considerable depths (Hargreaves, 2003). In contrast to PAR, which is energizing to photosynthesis, UVR is usually regarded as a stressor (Häder, 2003) and suggested to affect CO_2-concentrating mechanisms in phytoplankton (Beardall et al., 2002). Solar UVR is known to reduce photosynthetic rates (Steemann Nielsen, 1964; Helbling et al., 2003), and damage cellular components such as D1 proteins (Sass et al., 1997) and DNA molecules (Buma et al., 2003). It can also decrease the growth (Villafañe et al., 2003) and alter the rate of nutrient uptake (Fauchot et al., 2000) and the fatty acid composition (Goes et al., 1994) of phytoplankton. Recently, it has been found that natural levels of UVR can alter the morphology of the cyanobacterium *Arthrospira* (*Spirulina*) *platensis* (Wu et al., 2005b).

On the other hand, positive effects of UVR, especially of UV-A (315–400 nm), have also been reported. UV-A enhances carbon fixation of phytoplankton under reduced (Nilawati et al., 1997; Barbieri et al., 2002) or fast-fluctuating (Helbling et al., 2003) solar irradiance and allows photorepair of UV-B-induced DNA damage (Buma et al., 2003). Furthermore, the presence of UV-A resulted in higher biomass production of *A. platensis* as compared to that under PAR alone (Wu et al., 2005a). Energy of UVR absorbed by the diatom *Pseudo-nitzschia multiseries* was found to cause fluorescence (Orellana et al., 2004). In addition, fluorescent pigments in corals and their algal symbiont are known to absorb UVR and play positive roles for the symbiotic photosynthesis and photoprotection (Schlichter et al., 1986; Salih et al., 2000). However, despite the positive effects that solar UVR may have on aquatic photosynthetic organisms, there is no direct evidence to what extent and how UVR per se is utilized by phytoplankton. In addition, estimations of aquatic biological production have been carried out in incubations considering only PAR (i.e. using UV-opaque vials made of glass or polycarbonate; Donk et al., 2001) without UVR being considered (Hein and Sand-Jensen, 1997; Schippers and Lürling, 2004). Here, we have found that UVR can act as an additional source of energy for photosynthesis in tropical marine phytoplankton, though it occasionally causes photoinhibition at high PAR levels. While UVR is usually thought of as damaging, our results indicate that UVR can enhance primary production of phytoplankton. Therefore, oceanic carbon fixation estimates may be underestimated by a large percentage if UVR is not taken into account.

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* Corresponding author; e-mail ksgao@stu.edu.cn; fax 86–754–290–3977.

The author responsible for distribution of materials integral to the findings presented in this article in accordance with the policy described in the Instructions for Authors (www.plantphysiol.org) is: Kunshan Gao (ksgao@stu.edu.cn).

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