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Scientific note/Nota científica

Photosynthetic properties of three Brazilian seaweeds

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ABSTRACT – (Photosynthetic properties of three Brazilian seaweeds). Photosynthetic performance of distinct marine macroalgae, *Ulva fasciata* Delile (green alga), *Lobophora variegata* (J. V. Lamouroux) Womersley ex E. C. Oliveira (brown alga), and *Plocamium brasiliensis* (Greville) M. A. Howe & W. R. Taylor (red alga), were compared using a pulse amplitude-modulated fluorometer. The maximum quantum yield (F_v/F_m) ranged from 0.80 to 0.51, and the lowest value was found in *P. brasiliensis*. Under 400 µmol photons m^{-2} s^{-1} irradiance, the highest value of photochemical quenching (qP = 0.92 ± 0.13) was observed for *U. fasciata*. The red alga *P. brasiliensis* dissipated high amounts of excitation energy (qN = 0.56 ± 0.09), resulting in relatively low values for the effective quantum yield of PS-II (0.23 ± 0.04), as well as for the relative electron transport rate (3.3 ± 0.7). The high photosynthetic potential found for *U. fasciata* partially explains the species ability for rapid growth and high productivity.

Key words - Chlorophyll fluorescence, *Lobophora variegata, Plocamium brasiliensis*, *Ulva fasciata*

RESUMO – (Propriedades fotossintéticas de três macroalgas marinhas brasileiras). O desempenho fotossintético de três grupos distintos de macroalgas marinhas, *Ulva fasciata* Delile (alga verde), *Lobophora variegata* (J. V. Lamouroux) Womersley ex E. C. Oliveira (alga parda) e *Plocamium brasiliensis* (Greville) M. A. Howe & W. R. Taylor (alga vermelha), foi comparado com auxílio de um fluorímetro de pulso e amplitude modulada. O potencial fotoquímico máximo do PS II (F_v/F_m) variou de 0,80 a 0,51, sendo que os menores valores foram observados em *P. brasiliensis*. Sob a irradiância de 400 µmol fótons m^{-2} s^{-1}, o maior valor de dissipação fotoquímica (qP = 0,92 ± 0,13) foi observado para *U. fasciata*. A alga vermelha *P. brasiliensis* dissipou elevada quantidade de energia de excitação (qN = 0,56 ± 0,09), resultando em valores baixos de potencial fotoquímico efetivo do PS II (0,23 ± 0,04), e também de taxa relativa de transporte de elétrons (3,3 ± 0,7). O elevado potencial fotossintético encontrado para *U. fasciata* explica, parcialmente, a capacidade da espécie de crescimento rápido e de alta produtividade.

Palavras-chave - fluorescência da clorofila, *Lobophora variegata, Plocamium brasiliensis*, *Ulva fasciata*

Introduction

Chlorophyll fluorescence analysis allows noninvasive and fast measurements of key aspects of photosynthetic light capture and electron transport. For biological systems at room temperature, the overall chlorophyll fluorescence yield is usually low and most of the fluorescence emission originates from PSII antenna pigments (Krause & Weis 1991). Although PSII fluorescence is a minor pathway for excitation dissipation, it competes with the quantitatively more important energy dissipation routes of PSII photochemistry, such as excitation transfer to PSI and heat dissipation. Therefore, changes in photochemistry or in the two nonphotochemical routes (energy and heat emission) cause changes in the fluorescence yield from PSII (Krause & Weis 1991; Bolhàr-Nordenkampf & Öquist 1993).

Pulse amplitude-modulated (PAM) fluorescence measuring systems, originally developed for higher plants, have been used to measure chlorophyll fluorescence from algae and cyanobacteria (Schreiber *et al*. 1986, Büchel & Wilhelm 1993, Schreiber *et al*. 1995, Mouget & Tremblin 2002, Molina-Montenegro *et al*. 2005), as well as from photosymbiont-containing invertebrates such as corals (Yellowlees *et al*. 2003) and sponges (Beer

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& Ilan 1998). In this study, a pulse amplitude-modulated fluorometer was used to assess photosynthetic properties of three tropical seaweeds (green, brown and red algae). *Lobophora variegata* (J.V. Lamouroux) Womersley ex E. C. Oliveira (Heterokontophyta) and *Ulva fasciata* Delile (Chlorophyta) are widely distributed along the Brazilian coast from shallow waters up to depths of 26 and 13 m, respectively (Horta 2000). In contrast, *Plocamium brasiliensis* (Greville) M. A. Howe & W. R. Taylor (Rhodophyta) is restricted to the southern and southeastern coast of Brazil, growing from the intertidal zone to depths of 22 m (Horta 2000). The thalli of the first two species are foliose and expanded while *P. brasiliensis* thallus is foliose and abundantly branched. Comparative studies on the photosynthetic responses of different groups of tropical seaweeds are scarce (Necchi Júnior 2004), and this study was initiated as a contribution to reduce this gap.

Material and methods

Algal material – Specimens of the green alga *Ulva fasciata*, the brown alga *Lobophora variegata* and the red alga *Plocamium brasiliensis* were collected from Praia do Forno (Búzios, Rio de Janeiro State, Brazil – 22°46' S, 42°53' W) in March 2006. *U. fasciata* occurred in the intertidal and upper sub-littoral zone of rocky shores, while *L. variegata* and *P. brasiliensis* were found in the upper sub-littoral zone of the beach. Samples were collected from the rocky shore at 1 m depth and immediately placed in a vessel with seawater at 22 °C (ambient seawater temperature). The vessel was maintained in darkness for at least 20 minutes prior to fluorescence measurements. Three thalli of each species were used for measurements.

Chlorophyll-*a* fluorescence measurements – Chlorophyll fluorescence parameters were measured using a submersible diving-PAM system (Walz, Effeltrich, Germany), equipped with a blue LED (470 nm). The minimal fluorescence level in the dark-adapted state (F_o) was elicited by a weak probe of modulated light, whereas the maximum fluorescence level (F_m) was detected after a saturating pulse of actinic light (10,000 µmol photons m^{-2} s^{-1}), which is sufficient to close all reaction centers and drive photochemical quenching to zero. Variable fluorescence of dark-adapted samples (F_v) was calculated from F_m-F_o, and the maximum quantum efficiency of PS-II photochemistry was obtained from the ratio F_v/F_m. Samples were also exposed to 400 µmol photons m^{-2} s^{-1} until steady-state fluorescence emission (F_s) was obtained, and maximum fluorescence signal (F_m') of light-adapted samples was determined after a saturating pulse of actinic light. The effective quantum efficiency of PS-II ($\Phi_{PS-II} = F_m'-F_s / F_m'$) was obtained from light-adapted samples. The proportion of open PSII reaction centers under actinic light was determined by the photochemical quenching coefficient, $qP = (F_m'-F_s)/(F_m'-F_o)$, and the nonphotochemical quenching coefficient calculated from $qN = (F_m-F_m')/(F_m-F_o)$. The relative electron transport rate (rETR) was computed by using the equation ETR = PAR 0.5 Φ_{PS-II} 0.84 (Genty *et al*. 1989).

Statistics – Mean values were compared using Kruskal Wallis non-parametric ANOVA at 5% significance level ($P < 0,05$), using the software GraphPadInStat 3.01 (GraphPad Software Inc.).

Results and discussion

The three seaweed species showed significantly different responses in fluorescence parameters, although they occurred at similar positions on the boulders, and were, therefore, exposed to similar irradiances. Maximum quantum efficiency (F_v/F_m of dark-adapted samples) was significantly lower in *P. brasiliensis* and higher in *U. fasciata* than in *L. variegata* (figure 1A), suggesting that the red alga was photoinhibited at the highest light levels around noontime. In addition, the highest values observed in *U. fasciata* (0.80-0.83), seem to indicate an increased PSII function in comparison with the other two species.

The values for qP were not significantly different among the three species (figure 1B). Given that qP reflects the proportion of the PSII reaction centers in the open state, high values of qP can result either from high rates of electron transfer around PSII (high rates of Q_A re-oxidation) or from the occurrence of high nonphotochemical quenching processes. As qN describes any nonphotochemical process that reduces the yield of variable fluorescence, the lowest values for this parameter in *U. fasciata* (figure 1B) confirm that this alga efficiently utilizes trapped light energy. This is in agreement with high values of both photochemical yield of electron transport around PSII (Φ_{PS-II}, figure 1C) and relative electron transport rate (rETR, figure 1D) observed for this species. In contrast, it is evident in figure 1B that a higher amount of excitation energy is dissipated by nonphotochemical processes in *P. brasiliensis* than in the other two species, resulting in low values of Φ_{PS-II} and rETR (figure 1C and 1D). These results suggest that *P. brasiliensis* is a shade adapted species in accordance with the results found for another red alga *Palmaria palmata* (Linnaeus) Kuntze from the French coastline (Mouget & Trembling 2002). Under light intensities ranging from 10 to 150 µmol m^{-2} s^{-1}, *P. palmata* exhibited the lowest Φ_{PS-II} and qP values, as well as the highest level of energy dissipation through nonphotochemical quenching, in comparison to *Ulva* sp. and the brown alga

Fucus serratus Linnaeus (Mouget & Trembling 2002). Previous studies with freshwater algae also showed that the rhodophytes were typically shade-adapted plants and some of them can tolerate high irradiances due to the presence of high nonphotochemical quenching (Necchi Júnior 2005). Since the fluorescence parameters found in *L. variegata* were close to those found in the green alga, an efficient photosynthetic apparatus is also assumed to occur in this Dictyotales. Similar results were previously observed in *L. variegata* sampled from deep-water near Bermuda (Peckol & Ramus 1992).

Our results support the view of rapid growth potential and high net primary productivity of the opportunistic macroalgae *U. fasciata* as previously reported (Littler & Littler 1980, Mouget & Tremblin 2002). The sampling site can be subjected to drastic changes in water temperature during the summer, due to the upwelling phenomenon that occurs in the proximity (Valentin *et al*. 1978). High solar irradiation allied to cold water can change photosynthetic rates and increase photoinhibition (Gomez *et al*. 2001). Such conditions represent a natural laboratory for studies in the tropics and a better understanding of the photosynthetic responses of the macroalgal community is of major importance in the present scenario of potential global weather changes.

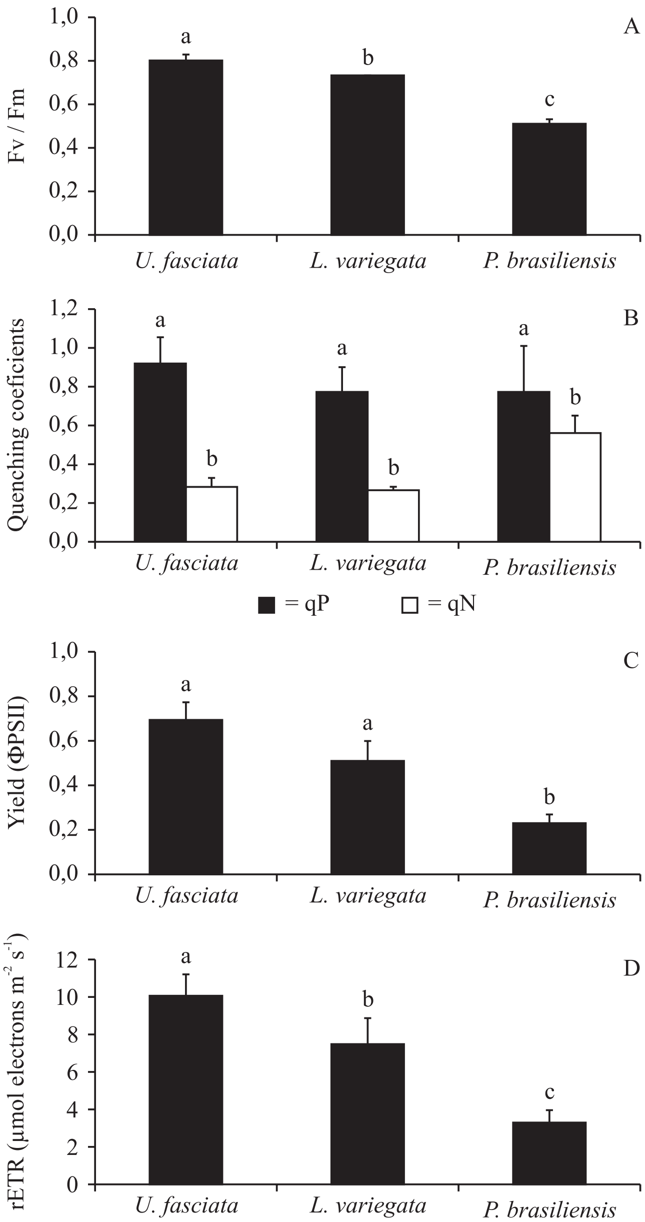

Figure 1. Photosynthetic parameters of three seaweeds: *Ulva fasciata*, *Lobophora variegata* and *Plocamium brasiliensis*. A. F_v/F_m, the maximum PS-II quantum efficiency of dark-adapted samples. B. qP and qN, the photochemical and nonphotochemical quenching coefficients, respectively. C. $\Phi_{PS\text{-}II}$, the effective PS-II quantum efficiency of illuminated samples. D. rETR, the relative electron transport rate. Distinct low caption letters represent statistically different means at $P < 0.05$, and bars represent standard deviations.

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