PHOTOSYNTHETIC PERFORMANCE OF MANGROVES *Rhizophora mangle* AND *Laguncularia racemosa* UNDER FIELD CONDITIONS

Antelmo Ralph Falqueto, Diolina Moura Silva, Renata Venturim Fontes

ABSTRACT – In mature mangrove plants *Rhizophora mangle* L. and *Laguncularia racemosa* Gaerth. growing under field conditions, photosystem 2 (PS2) photochemical efficiency, determined by the ratio of variable to maximum fluorescence ($F_v/F_m$), increased during the day in response to salinity in the rainy seasons. During the dry season, fluorescence values ($F_o$) were higher than those observed in rainy season. In addition, $F_o$ decreased during the day in both season and species, except for *R. mangle* during the dry season. A positive correlation among $F_v/F_m$ and salinity values was obtained for *R. mangle* and *L. Racemosa* during the dry and rainy seasons, showing that photosynthetic performance is maintained in both species under high salinities. Carotenoid content was higher in *L. Racemosa* in both seasons, which represents an additional mechanism against damage to the photosynthetic machinery. The chlorophyll content was not affected by salinity in either species.

Keywords: chlorophyll fluorescence, photosynthetic pigments, photosystem.

DESEMPENHO FOTOSSINTÉTICO DE *Rhizophora mangle* E *Laguncularia racemosa* EM CONDIÇÕES DE CAMPO

RESUMO – Em plantas adultas de *Rhizophora mangle* L. e *Laguncularia racemosa* Gaerth. crescendo em condições de campo, a eficiência fotoquímica do fotossistema 2 (FS2), determinada pela razão fluorescência variável : fluorescência máxima ($F_v/F_m$), aumentou durante o dia em resposta à salinidade, durante a estação chuvosa. Durante a estação seca, os valores de $F_o$ foram superiores aos observados durante a estação chuvosa. Além disso, $F_o$ reduziu-se ao longo do dia em ambas as estações e espécies, exceto para *R. mangle* durante a estação seca. Uma correlação positiva entre os valores de $F_v/F_m$ e da salinidade foi obtida em *R. mangle* e *L. racemosa* durante as estações seca e chuvosa, mostrando que o desempenho fotosintético é mantido em ambas as espécies sob altas salinidades. O conteúdo de carotenóides foi maior em *L. racemosa*, em ambos as estações, representando um mecanismo adicional contra danos à maquinaria fotosintética. O conteúdo de clorofila não foi afetado pela salinidade das espécies estudadas.

Palavras-chave: Fluorescência da clorofila, pigmentos fotosintéticos e fotossistema.

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2 Departamento de Ciências da Saúde, Biológicas e Agrárias da Universidade Federal do Espírito Santo (UFES), São Mateus-ES.
3 Departamento de Ciências Biológicas da UFES. E-mail: <biovegetal@terra.com.br>
4 Programa de Pós-Graduação em Ciências Biológicas da UFES.
1. INTRODUCTION

Rhizophora mangle L. and the Laguncularia racemosa Gaerth. mangroves are two major species in the district of Vitoria, Espirito Santo, Brazil and dominant in the American Atlantic coastlines. These species grow in environments with widely ranging salinity, from near freshwater to above seawater salinity (LOVELOCK and FELLER, 2003; SUARÉZ, 2003; SOBRADO, 2004; SOBRADO, 2005). Salinity constitutes the main stressor of the development and productivity of mangrove forests (MEDINA et al., 1990; SOBRADO and BALL, 1999). Mangrove species more tolerant to salinity may function with less efficient water transport, which may be related to more conservative water use (SOBRADO, 2004). Krauss and Allen (2003) suggested high salinity tends to favor the development, establishment and physiology of R. mangle. However, other studies show that L racemosa is more tolerant to the negative effects of salinity (SOBRADO, 2004). Evidence for less salt sensitivity in mangrove species includes biochemical adaptations by wich mangroves counter the high osmolarity of salt, like accumulation of compatible solutes or enhanced gland secretion (TAKEMURA et al., 2000; KRAUSS and ALLEN, 2003; SOBRADO, 2004). In contrast, responses of mangrove to salinity reflect alterations in photosynthesis, photosynthetic pigment content, transpiration rate, and enzyme activities. Generally, these negative effects also associated with other environmental factors, e.g., high light levels (TAKEMURA et al., 2000; KRAUSS and ALLEN, 2003).

The photosynthetic performance of R. mangle and L. racemosa mangrove species in the equatorial region of Brazil is little understood. It is known that integrity of membranes, activity of several enzymes, nutrient acquisition, photosynthetic pigment content, gas exchange and photosynthetic apparatus function are affected by high NaCl concentrations (ZHU, 2001). In halophytes, some studies have showed that salinity inhibits photosystem 2 (PS2) activity, while others indicate the opposite (TAKEMURA et al., 2000; LU et al., 2002; QIU-FANG et al., 2005). Avicennia germinans Stearn. (Avicenniaceae). R. mangle and L. Racemosa are the dominant trees at the study site, while A. Germinans is little represented. All data were collected from ten trees, which varied in height from 2–4 m. Interstitial water was collected in the morning (9 a.m.), midday (1 p.m.) and afternoon (5 p.m.) using 2.5 cm diameter PVC tube inserted at -0.2 m sediment depth, according to the method of Miller and Ullman (2004). Salinity measures of interstitial water were accomplished immediately after collecting the water in the tubes, using a portable conductometer SCHOT Mod. LF1.

Chlorophyll fluorescence parameters were determined in situ on fully expanded young leaves of R. mangle and L. Racemosa, in the morning, midday and afternoon using a portable Chlorophyll Fluorescence System (Handy-PEA, Hansatech, Norfolk, England) after 30 min of dark adaptation, using specially designed...
clips attached to the leaves. These same leaves were used for the determination of photosynthetic pigment contents (below). Each leaf was exposed to a saturation pulse of light (750 μmol m⁻² s⁻¹; the value was obtained from a saturation curve) for 5 s. Initial fluorescence (Fo) and PS2 photochemical efficiency (Fv/Fm) were calculated automatically.

Chlorophyll and carotenoid contents were determined in the morning using the spectrophotometric method suggested by Arnon (1949). Chlorophyll a (Chl a), chlorophyll b (Chl b), chlorophyll a/b ratio and carotenoids (Car) were calculated using the following equations, suggested by Hendry Grime (1993): Chl a (mg/L) = 12.7 x A₆₆₅ - 2.69 x A₆₄₅; Chl b (mg/L) = 22.9 x A₆₄₅ - 4.68 x A₆₆₃; Car = [A₄₇₀ + 0.114 x A₆₆₃ - 0.638 x A₆₄₅] x V / 112.5 x Weight of the fresh matter of the leaf (g), where V = volume of the acetone extract in cm³ and A = absorbance at the specified wavelength (nm), measured with a 1 cm cuvette.

Each data collection consisted of ten repetitions, in a randomized block design. For salinity, Fo and Fv/Fm, statistical comparisons were made between dry and rainy seasons and between times during the day. Chlorophyll and carotenoid content values were compared between species and between seasons. Salinity and Fv/Fm values were correlated in both species and seasons. Results were examined by one-way analysis of variance (ANOVA) and differences between means were assessed using Tukey test at 5% significance level (STATSOFT, 1995).

3. RESULTS AND DISCUSSION

Significant increase in salinity was observed in the rainy season at 1 p.m. and 5 p.m. in relation to that at 9 a.m. (Table 1). Furthermore, the salinity values obtained in this season were higher than those in the dry season. During the rainy season, PS2 photochemical efficiency (Fv/Fm) of dark-adapted leaves sampled at 9 a.m. were 0.73 and 0.69 for R. mangle and L. racemosa, respectively (Table 1). These values were significantly lower than those obtained at 1 and 5 p.m. and were inversely related to initial fluorescence values (Fo).

During the dry season, Fo mean values were higher than those observed in the rainy season for both mangrove species. In the dry season, Fo values decreased significantly in L. racemosa during the day, from 1027 in the morning, to 875 and 675 in the midday and afternoon, respectively (Table 1). In contrast, Fv/Fm values increased significantly during the day for L. racemosa: 0.66, 0.74 and 0.80 at 9 a.m., 1 and 5 p.m., respectively. For R. mangle, the Fv/Fm values were 0.68 at 9 a.m. and 0.77 at 1 and 5 p.m. (Table 1). Carotenoid content was higher to L. racemosa in both seasons. There were no significant differences for chlorophyll content between species and between seasons.

Fv/Fm reflects the PS2 potential efficiency and it is used as indicators of plant photosynthetic performance (KAO and TSAI, 1999; SHIRKE and PATHRE, 2003; RIBEIRO et al., 2004). In this study, the increase observed in Fv/Fm during the day for R. mangle and L. racemosa, in both seasons, can be attributed to a decrease in Fo, although the Fo values did not present a statistically reduction in R. mangle during the dry season. Fo originates exclusively from the PS2 light harvest complex (LHC2) after the application of low red light on leaves adapted to the dark (LICHTENTHALER et al., 2005) and its values are, generally, strongly related to photo inhibition phenomena. In addition, during the rainy season, Fv/Fm of dark-adapted leaves increased similarly during the day in response to increases in salinity for both species. These results strongly suggest that R. mangle and L. racemosa increase their photosynthetic efficiency in response to increases in salinity levels.

Several studies have shown that high salinity causes a decrease of photosynthetic efficiency in mangrove species grown in greenhouses under different concentrations of NaCl. However, the effects of salinity on photosynthetic parameters of mangrove species under field conditions are contradictory. The main reason for this contradiction is the large variation of field environmental conditions. Thus, results obtained in a specific mangrove are cannot be extrapolated to mangroves situated in other regions.

In this study, a positive correlation (r² = 0.99) (not shown) among Fv/Fm and salinity values was obtained for both species and seasons, indicating that R. mangle and L. racemosa presented high tolerance and adaptability at high salinity. Halophytic plants are tolerant to salinity because they are able to take up water through the accumulation of inorganic ions or other compatible solutes such as betaine and proline. Consequently, the osmotic potential decreases, which in turn attracts water into the cell and enables to maintain pressure potential (MOGHAIEB et al., 2004).
Leaf chlorophyll content (Chl a, Chl b, Chl a/b ratio) on a fresh mass basis showed no significant difference for both (daily and seasonal) periods (Table 1). Lu et al. (2002) observed that salt stress had no effects on the photosynthetic pigment composition in halophyte *Suaeda salsa*, grown outdoors in plastic pots, subjected to salt concentrations up to 400 mM. Thus, chlorophyll content in *Rhizophora mangle* and *Laguncularia racemosa* seems to be insensitive to salinity variations during the day and in both dry and rainy seasons.

*Rhizophora mangle* and *Laguncularia racemosa* differed in carotenoid content (Table 1). Higher carotenoid content was observed in *L. racemosa* in both seasons. Carotenoids play important roles in plants: they act as pigment antenna, enhancing the reception of luminous energy for the reaction centers, and protect chlorophyll against photoxidative damage (GONÇALVES et al., 2001; BEHERA and CHOUDHURY, 2002). During the protective action, they are degraded. It is possible that *L. racemosa* is adapted to maintain higher carotenoid levels in its cells. On the other hand, low carotenoid contents can be a consequence of β-carotene degradation and subsequent zeaxanthin synthesis (through de-epoxidation of violaxanthin to antheraxanthin and to zeaxanthin), which are also involved in protection against photoinhibition. This is a photoprotective mechanism and allows excess energy to be dissipated. Conversion of violaxanthin to zeaxanthin has been observed in other mangrove species under high salinity (SOBRADO and BALL, 1999).

It is probable that the increase in both synthesis and accumulation of antioxidative pigments (carotenoids) in *L. racemosa* during both dry and rainy seasons represents an additional mechanism against damage to the photosynthetic machinery. Since $F_{v}/F_{m}$ ratios of 0.75 - 0.85 have been considered normal for unstressed plants (HUNT, 2003; OLIVEIRA et al., 2006), it can be suggested that *Rhizophora mangle* and *Laguncularia racemosa* were able to maintain photosynthetic activity in response to salinity increases because of their protection mechanisms.

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4. REFERENCES


