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Photochemical activity of *Cattleya harrisoniana* (Orchidaceae) after sunfleck exposure

Atividade fotoquímica de *Cattleya harrisoniana* (Orchidaceae) após exposição ao sunfleck

Jadson Bonini Zampirollo[1], Clodoaldo Leites Pinheiro[3], Diolina Moura Silva[2] & Antelmo Ralph Falqueto[1*]

1Departamento de Ciências Agrárias e Biológicas, Centro Universitário Norte do Espírito Santo, Universidade Federal do Espírito Santo, 29932540 São Mateus/ES, Brazil. 2 Departamento de Ciências Biológicas, Universidade Federal do Espírito Santo, 29075910 Vitória/ES, Brazil. 3 Embrapa Pecuária Sul, 96401970 Bagé/RS, Brazil.

* Autor para correspondência: antelmo.falqueto@ufes.br

Resumo Parâmetros da fluorescência da clorofila a foram investigados em plantas de orquídea (*Cattleya harrisoniana* Batem Ex. Lindl.) submetidas à alta luz durante 35 minutos, simulando uma mancha solar. Reduções em Fv'/Fm', ΦPSII e qP após a exposição à alta luz foram atribuídas à dissipação não-radioativa da energia de excitação, como indicado pelo aumento dos valores de 1-Fv'/Fm', os quais contribuem para a auto-regulação do fotossistema II (FSII) evitando a super-redução do aceptor primário de elétrons, quinona A (QA). Os resultados também indicam a ocorrência de fotoinibição dinâmica, evidenciada por meio da recuperação de todos os parâmetros fotossintéticos após a exposição a alta luz.

Palavras-chave: Luz, Fluorescência da clorofila *a*, Dissipação de energia não-radioativa, Ecofisiologia.

Abstract Parameters of chlorophyll (Chl) a fluorescence were investigated in orchid plants (*Cattleya harrisoniana* Batem Ex. Lindl.) submitted to high light during 35 minutes, simulating a sunfleck. Reductions in Fv'/Fm', ΦPSII and qP after high light were attributable to non-radiative energy dissipation, as indicated by the increase of 1-Fv'/Fm' values, which contributed to a down regulation of photosystem II (PSII) avoiding the overreduction of the primary electron acceptor, quinone A (QA). Our results also indicated the occurrence of dynamic photoinhibition, evidenced through of recovery back to control values of all photosynthetic parameters after high light.

Keywords: Light, Chlorophyll a fluorescence, Non-radiative energy dissipation, Ecophysiology.

Introduction

Inside of a forest, sunflecks expose the leaves to full sunlight for a few minutes. Sunflecks count up to 85% of the total irradiance available during the day and are important to increase both growth and development of plants growing under canopy (WAY; PEARCY, 2012). Sunflecks also play a role in the carbon metabolism of lower leaves in dense crops that are shaded by the upper leaves of the plant (CHAZDON; PEARCY, 1991; KURSAR; COLEY, 1993; WAGNER; MCGRAW, 2013). However, depending of intensity and duration of sunflecks, the leaves should be exposure to strong light intensity resulting in inhibition of the activity of photosystem II (PSII) or photoinhibition (MURATA et al., 2007). The photoinhibition is characterized by inactivation and damage to the D1 protein, reduction of the maximum quantum efficiency of CO_2 uptake and the accumulation of oxygen reactive species (ROS) which damage the cell membranes (TAKAHASHI; BADGER, 2011). Further, the reduction of the maximum photosynthetic rate reduces the carbon gain and plant growth (VAN HEERDEN et al., 2007; GONÇALVES et al., 2010; TAKAHASHI; BADGER, 2011; ADAMS III et al., 2013). The phenomenon of photoinhibition is unavoidable in all photosynthetic organisms (MURATA et al., 2007).

However, several mechanisms should be used by plants to minimizing the effects of photoinhibition on photosynthetic apparatus, repairing effectively the photodamage on PSII such as reversible phosphorylation of PSII core subunits and monomerization and migration of the PSII core from the grana to the stroma lamellae (ARO et al., 2005). In addition, an efficient enzymatic and non-enzymatic system can scavenging the ROS formed due high light (TAKAHASHI; BADGER, 2011; GHOLAMIA et al., 2012). Also, the high light should be dissipated as thermal energy (qE), fluorescence emission, cyclic electron flow (CEF) around photosystem I (PSI), photorespiratory pathway and heat dissipation and transference from PSII to FSI (NPQ) (RALPH; GADEMANN, 2005; ARO et al., 2005; TAKAHASHI; BADGER, 2011), which is connected directly to the xanthophyll cycle. Thus, the excitation energy is dissipated as heat (thermal dissipation) and therefore protect against photoinhibition (KRAUSE; WEIS, 1991; ESSEMINE et al., 2012).

The effects of sunflecks on photochemical activity were registered in other plant species, such as *Swietenia macrophylla* King (Meliaceae) and *Minquartia guianensis* Aubl. (Olacaceae), *Bauhinia forficate* Link (Fabaceae) and the late successional *Esenbeckia leiocarpa* Engl. (Rutaceae) (DIAS; MARENCO, 2006; PORTES et al., 2006). However, in orchids plants, no study regarding the effects of high light simulating sunfleck was made. Thus, in this study, we evaluated the Chl *a* fluorescence in *Cattleya harrisoniana* (Orchidaceae) Batem ex. Lindl. an orchid species adapted to partial shade.

Methods

Cattleya harrisoniana specimens, obtained from a private nursery (São Mateus, Espírito Santo State, Brazil), were used in this study. In this nursery, the plants were grown under approximately PPFD 100-200 μmol $m^{-2}s^{-1}$ and temperature of the air ranging from 24 to 30°C until the begin of experiment. Relative humidity was 70-80%. The plants were watered daily and fertilized with a nitrate-based commercial fertilizer (N: P: K ratio of 1: 1: 1) when necessary. The experiment consisted of exposure of plants to full sunlight (which occurred at 13h under ~2260 μmol $m^{-2}s^{-1}$) in a clear day for 35 min. Before (at 8h), the first Chl *a* fluorescence measurement (considered as control) was carried out on plants raised in the nursery. Afterwards, the measurements were performed during the day in intervals of 2 hours until 19h. In order to test the recovery capacity of plants, a new evaluation was performed after 24 hours (8h after the last day). Irradiance was recorded with a quantum sensor (QSPAR, Hanstech, UK). Chl *a* fluorescence measurements were performed on intact leaves fully expanded using a pulse-amplitude-modulated (PAM) Chl fluorimeter (FMS-2, Hansatech, UK). Measurements were taken of the middle part of the leaf. The following parameters were determined: initial fluorescence, Fo., maximal efficiency of PSII photochemistry, Fv/Fm; effective efficiency of PSII photochemistry, Fv'/Fm'; the non-radiative energy dissipation, 1 – (Fv'/Fm'); photochemical quenching coefficient, qP = (Fm' - Fs)/(Fm' - Fo'); actual quantum yield of PSII electron transport in light-adapted state and φPSII = (Fm' - Fs)/Fm' (GENTY et al., 1989). Data were subjected to analysis of variance (ANOVA). A Tukey test ($p<0.05$) was used to compare means among treatments.

Results

The photosynthetically active radiation (μmol $m^{-2}s^{-1}$) and leaf temperature (°C) of *C. harrisoniana* were significantly ($p\leq0.05$) high through the duration of the sunfleck and decreased until 19h. After 24 hours (8h after the last day), both RFA and leaf temperature were nearly to control conditions, evidencing the recovery to initial conditions observed at 8h (Fig 1).

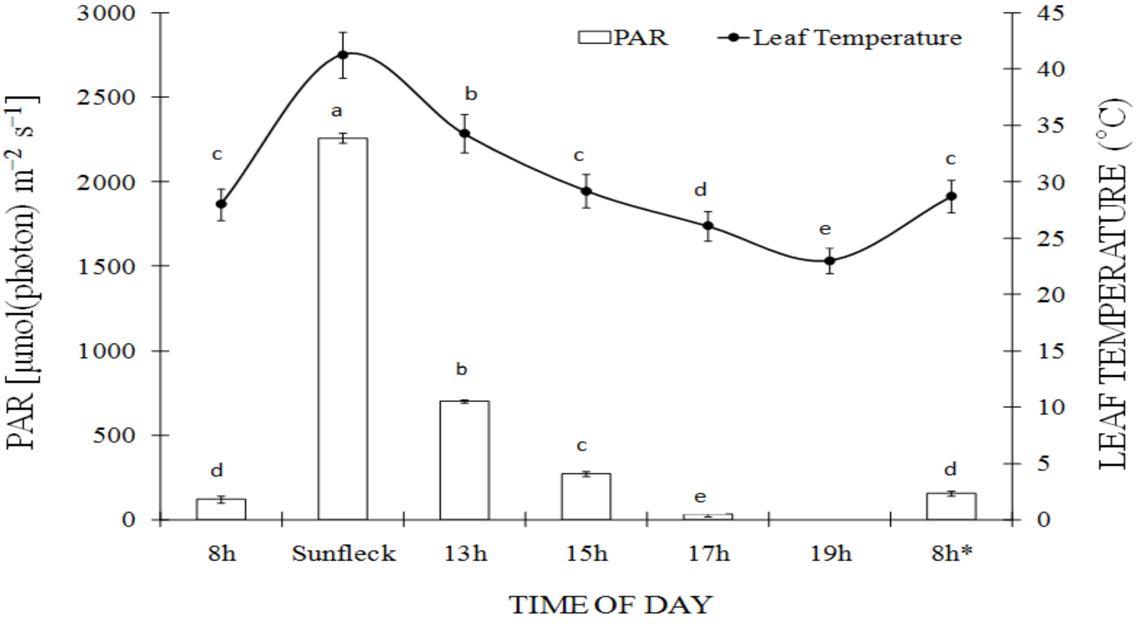

Figure 1 Daily course of photosynthetically active radiation - PAR [μmol(photon) $m^{-2}s^{-1}$] and leaf temperature (°C) of C. harrisoniana. Values are means (±S.E.) for four plants (Tukey test, $p \leq 0.05$).

Figure 2 shows the relationship between Chl *a* fluorescence parameters evaluated in *C. harrisoniana* specimens submitted to high light. The Fv'/Fm' ratio, which expresses the effective efficiency of PSII photochemistry measured in light-adapted samples (ROHÁCEK, 2002), was initially unaffected by high light. However, a strong decrease in Fv'/Fm' values of about -68% (0.227 to 0.071 from 13 to 19h, respectively) occurred 6h after sunfleck (Fig. 2A).

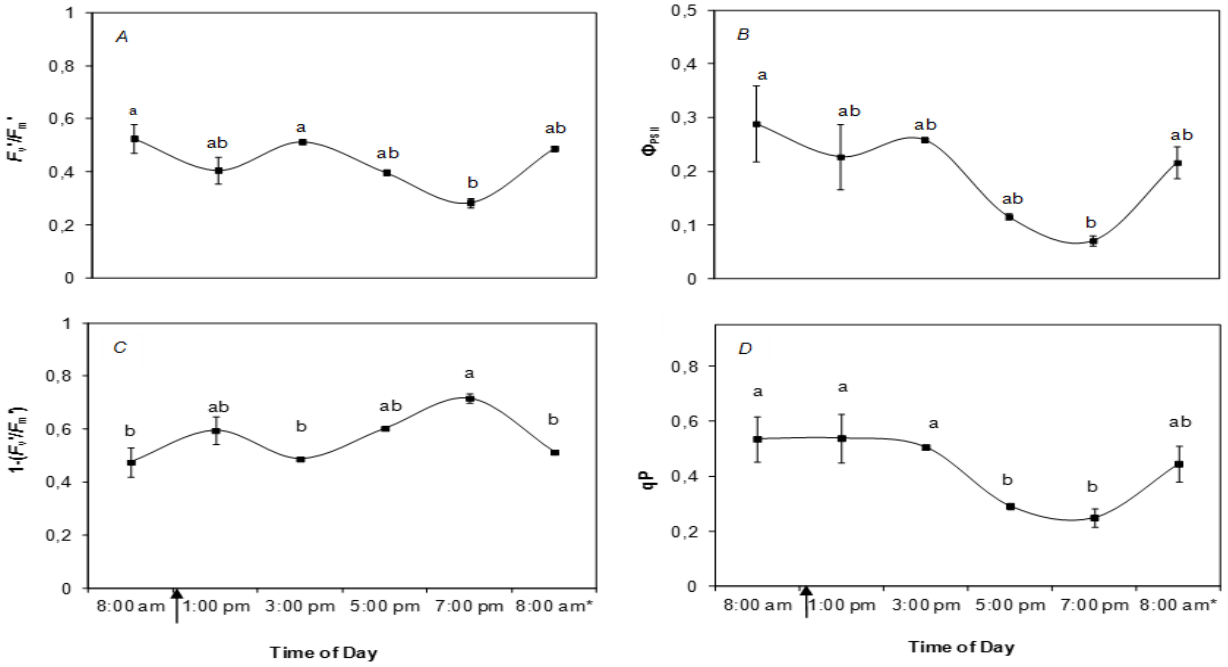

Figure 2 Effective efficiency of PSII photochemistry in dark-adapted state (Fv'/Fm' - A), actual quantum yield of PSII electron transport in light-adapted state (φPSII – B), the non-radiative energy dissipation [1 – (Fv'/Fm') – C], the photochemical quenching coefficient (qP – D) in specimens of *C. harrisoniana* submitted to high light during 35 minutes, simulating a sunfleck. Arrow indicates the application of sunfleck (13h). Values are means (±S.E.) for four plants (Tukey test, $p \leq 0.05$).

Discussion

The decrease of ΦPSII in *C. harrisoniana* after sunfleck suggest that lower light energy could be delivered to the reactions center (MÜLLER et al., 2001), reflecting in reduced PSII photochemical efficiency and dissipation values (Fig. 2A,B). The decline of Fv'/Fm', ΦPSII and qP after high light was attributable to non-radiative energy dissipation, as indicated by the increase of 1-Fv'/Fm' values. Increases in non-radiative dissipation of excitation energy in response to high light decrease the probability of photodamage by relieving the excitation pressure on PSII, resulting in the maintenance of a greater openness of PSII centers. In this study, the relevance of non-radiative dissipation of excitation energy process in *C. harrisoniana* appeared especially during the first times after high light exposition. The non-radiative dissipation of excitation energy is one of the most important photoprotective processes and it should be used to quantify the operation of photoprotective processes as well as the extent of photoinhibitory damages. In this study, the increase of dissipation (1-Fv'/Fm') followed to the decrease of parameters related to photochemical efficiency (Fv'/Fm', ΦPSII and qP) contributed to a down regulation of PSII avoiding the overreduction of the primary electron acceptor (QA) in *C. harrisoniana* specimens. Thus, these results give us evidence about the capacity of *C. harrisoniana* to coupe with high energy of excitation common in the natural environment, which are subject to fluctuations in irradiance on a time-scale ranging from seconds to seasons and must cope with the quantity of the photons varying over several orders of magnitude (ŠTROCH et al., 2004).

Augusti et al. (2001) and Hanachi et al. (2014) discussed the role of these non-photochemical dissipations process such as mechanism of photoprotection in *Ramonda serbica* Panc. (Gesneriaceae) under drought stress and in eggplant (*Solanum melongena* L.) cultivars growing on different salt concentrations, respectively. During drought stress, the plants of *R. serbica* showed an increase of the content of zeaxanthin (and antheraxanthin), which are a prerequisite for non-photochemical dissipations process (AUGUSTI et al., 2001). Others components, such as ascorbate and glutathione, also are efficient mechanism of protection and it could be efficiently utilized in response to high light. In other studies, significant increases in non-photochemical dissipations also were reported in stressed plants, with significant reduction in the maximum quantum yield of PSII photochemistry (Fv/Fm) and the electron transport rate (MORADI; ISMAIL, 2007; ZRIBI et al., 2009).

Conclusion

The results of the present study indicate the occurrence of dynamic photoinhibition in *C. harrisoniana*, evidenced through of recovery back to control values of all photosynthetic parameters analyzed after high light. Non-radiative dissipation has a major photoprotective mechanism against photoinhibition in *C. harrisoniana* after sunfleck.

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