# Photoinhibition of primary photosynthetic processes in *Polytrichum commune*: Analysis of driving factors affecting species resistance

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## INTRODUCTION

Photoinhibition of photosynthesis is a well-known phenomenon in higher plants. In mosses, photoinhibition happens especially in shade-adapted species, when they are exposed to high light doses (*e.g.* Murray et al. 1993, Hájek et al. 2009). Photoinhibition of chloroplastic primary processes of photosynthesis occurs because light intensity exceeds the capacity/activity of the photosynthetic electron transport chain, leading to inactivation and damage of the photosynthetic apparatus, photosystem II (PSII) in particular.

Mosses from sunny habitats are considered photoinhibition tolerant because their photosynthetic apparatus has photoprotective mechanisms typical of vascular plants and green algae. Mosses possess "vascular plant-type" light-harvesting complex protein PsbS and "algal-type" light-harvesting complex stress-related protein (LHCSR). In mosses, LHCSR and PsbS may migrate between PSII and PSI in order to quench excitation energy (Furukawa et al. 2019). Recent studies (*e.g.* Dikaios et al. 2019) confirmed the role of LHCSR proteins in thermal dissipation in photoinhibited mosses. These two proteins are involved into non-photochemical quenching of absorbed light energy, protecting PSII from overenergization and photooxidation of PSII components.

In this study, resistence of *P. commune* has been investigated by chlorophyll fluorescence. Slow Kautsky kinetics supplemented with the analysis of quenching mechanism was applied. We hypothesized medium-high resistence in this moss since it was collected from treeless, open, sunny alpine environment.

## MATERIAL AND METHODS

*Polytrichum commune* was collected in the Jeseníky Mts (50.08637 N, 17.23079 E) in locality Tabulové skály rocks (1 415 m a. s. l.). In the laboratory, samples were sprayed regularly with distilled water to reach optimum hydration. Then, *P. commune* was exposed to three different photoinhibitory treatments (PIT): (1) 1 200 µmol $m^{-2}$ $s^{-1}$ of photosynthetically-active radiation (PAR) for 60 min., (2) 1 500 µmol $m^{-2}$ $s^{-1}$ for 60 min., and (3) 1 500 µmol $m^{-2}$ $s^{-1}$ for 120 min. Before the PIT, immediately after the PIT and afterwards, during recovery, chlorophyll fluorescence parameters were measured by a Handy Fluorcam HFC-010 (Photon Systems Instruments, Czech Republic). Potential ($F_V/F_M$) and effective quantum yield ($\Phi_{PSII}$) of photochemical processes in photosystem II (PSII) were measured, as well as non-photochemical quenching (qN).

## RESULTS AND DISCUSSION

The PIT induced a decrease in $F_V/F_M$ and $\Phi_{PSII}$. The decrease found immediately after the PIT was dose dependent and the values reached their minimum. Then, during recovery time, both $F_V/F_M$ and $\Phi_{PSII}$ were increasing. The increase was faster and getting

closer the pre-photoinhibitory values in $F_V/F_M$ rather than $\Phi_{PSII}$. Recovery of $\Phi_{PSII}$ remained uncompleted even after 3 h of recovery time. In $F_V/F_M$ parameter two distinct phases of recovery were found: fast recovery phase, within 20 min. from PIT, and slow recovery phase, after 20 min. from PIT. In $\Phi_{PSII}$ parameter recovery was linear. Non-photochemical quenching showed a PIT dose-dependent increase and slow, uncompleted recovery during 3 hours. Non-photochemical quenching (qN), when plotted against $\Phi_{PSII}$, showed more or less linear relation for the data recorded immediately after the PIT and during recovery. Absolute qN values were dose-dependent (*see* Fig. 1). The most severe PIT led to the most remarkable induction of photoprotection mechanisms. See in Fig. 1 the highest qN increase from control after PIT.

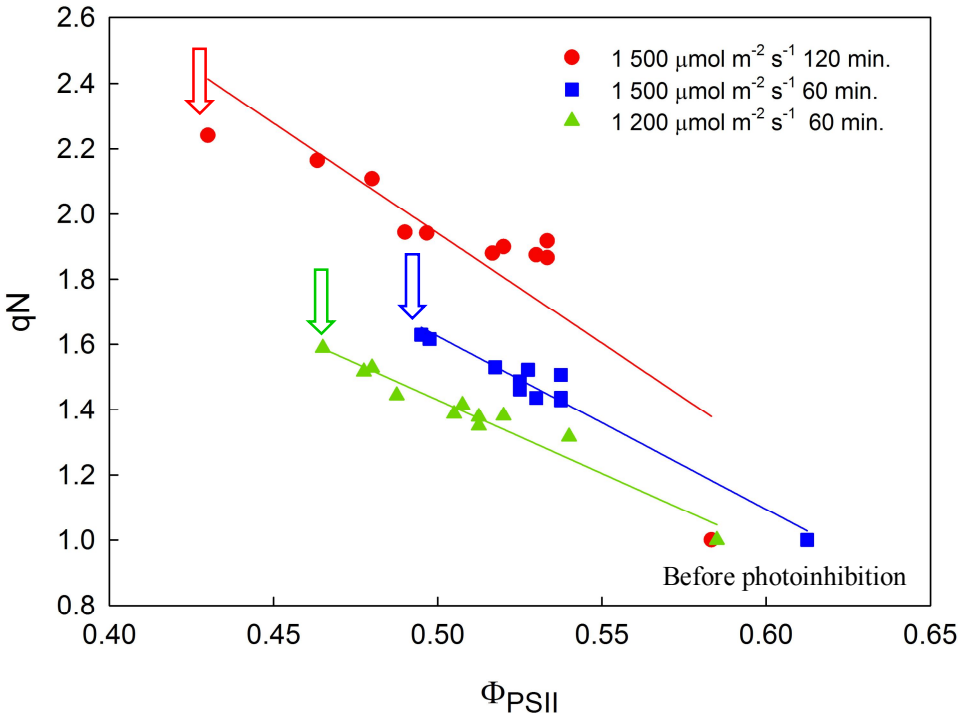


**Fig. 1.** Relation of non-photochemical quenching (qN, dependent variable) to effective quantum yield of PSII ($\Phi_{PSII}$) in *Polytrichum commune* exposed to particular photoinhibitory treatments: 1 500 µmol $m^{-2}$ $s^{-1}$ of PAR) for 120 min. (red symbols), 1 500 µmol $m^{-2}$ $s^{-1}$ PAR for 60 min. (blue symbols), and 1 200 µmol $m^{-2}$ $s^{-1}$ PAR for 60 min (green symbols). The qN values recorded immediately after the photoinhibitory treatments are indicated by the arrows. Values are normalized to control due to the differences among initial values in the samples.

## CONCLUSION

*Polytrichum commune* could be considered relatively resistant to photoinhibition since it showed effective recovery of $F_V/F_M$ (more than 92%) and $\Phi_{PSII}$ (more than 87%) when exposed to PIT. Non-photochemical quenching (qN) did not fully recover from the peak values recorded immediately after the PIT in the following 3 hours, indicating that protective mechanisms remained active during the whole period; however the first two treatments (1 200 µmol $m^{-2}$ $s^{-1}$ PAR for 60 min. and 1 500 µmol $m^{-2}$ $s^{-1}$ PAR for 60 min.)

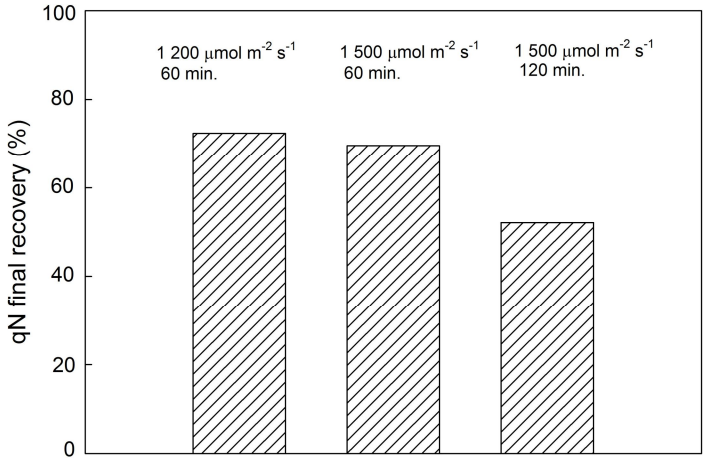


**Fig. 2.** Relative recovery of non-photochemical quenching (qN) recorded for each photoinhibitory treatment (*see* included values of PAR and duration of the treatments) after the recovery period (120 min.).

showed similar, quite high qN final recovery values (around 70%), while the third one (1 500 μmol $m^{-2}$ $s^{-1}$ PAR for 120 min.) presented low final recovery value (52%). This is indicative of the fact that small increase in light intensity (300 μmol $m^{-2}$ $s^{-1}$ PAR) had small effect on the photosynthetic apparatus, while the increase of the time of PIT (doubled time in treatment 3) had high impact on protective mechanism response. Nevertheless this response was, in all three cases, effective enough to attain functional recovery of the photosynthetic machinery.

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