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A mechanistic model for the estimation of the quantum yield of photochemistry based on light, temperature, and chlorophyll a fluorescence

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Highlights: By studying chlorophyll a fluorescence emissions from a range of light intensities in Scots pine saplings acclimated to different temperatures, we aim to build a model to interpret chlorophyll a fluorescence capable of estimating the quantum yield of photochemistry (ϕ_P).

Keywords: chlorophyll a, fluorescence, Scots pine, *Pinus sylvestris* L.

INTRODUCTION

The analysis of the chlorophyll a fluorescence emitted from vegetation is an approach to estimate the light use efficiency (LUE), a term used for the estimation of gross primary productivity (GPP) by remote sensing, and the measurement of changes in fluorescence can be used to infer information about changes in ϕ_P, which is a good proxy of LUE.

Nevertheless, fluorescence is only one of the possible pathways in which the absorbed excitation energy can be used, and it competes with two other pathways: photochemistry, and thermal energy dissipation. The link between photochemistry and fluorescence is not trivial, and variations in fluorescence can be caused by both changes in photochemical or in non-photochemical energy utilization. This difficulty can be solved by studying chlorophyll a fluorescence by a saturating light pulse technique, which momentarily saturates the photochemical pathway and allows ϕ_P estimation from fluorescence parameters.

But this active technique cannot be implemented from large distances as those of remote sensing, where the sun-induced passive fluorescence is used instead. Thus, linking fluorescence to LUE in the absence of saturating pulse technique still remains to be improved.

The aim of this study is to develop a mechanistic model capable of bypassing the lack of saturating pulse capabilities in sun-induced fluorescence measurements by estimating the status of the reactions centres and quinone pools, the dynamics of photochemical capacity and non-photochemical quenching (NPQ), and energy fluxes from variations in fluorescence and using light and temperature to constrain photoinhibition and NPQ.

MATERIAL AND METHODS

In summer 2011, a total of 17 Scots pine (*Pinus sylvestris* L.) saplings growing in the field were transferred to a weather chamber and acclimated to different temperatures ranging from -5 to 40 °C. For each temperature, current-year needles were exposed to different light treatments ranging from 50 to 1500 μmol photons m^{-2} s^{-1} during an hour, and fluorescence emissions were recorded every second by a monitoring-PAM system (Heinz Walz GmbH, Germany). Fluorescence emissions were also recorded during sapling recovery in the darkness after the light treatments. During the whole process, a series of saturating light pulses (1s, 4000 μmol photons m^{-2} s^{-1} actinic light) were also given in order to get fluorescence parameters necessary to estimate ϕ_P.

RESULTS AND DISCUSSION

The maximum quantum yield of the photosystem II (Fv/Fm) was highest around 20 °C, and decreased gradually towards cooler temperatures. Fv/Fm decreased drastically towards warmer temperatures.

NPQ building under light reached higher values towards the highest light treatments, and reached faster a constant value under warm conditions, except in the coldest temperatures studied. NPQ relaxation in the darkness reached faster its initial values under warmer conditions except under -5 °C, where it was kept steady or even increased slightly.

The results concerning parameterization and model development are being developed and will be presented in the 7th International Conference on Functional-Structural Plant Models.