Seasonal variation of photoinhibition of photosynthesis in bark from *Populus tremula* L.

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Abstract

In the bark of *Populus tremula* L. photochemical efficiency of photosystem 2 (PS2) determined as $F_v/F_m$ decreased during winter. The strongest reduction was found after cold periods. The degree of reduction depended on irradiance since the lowest levels of $F_v/F_m$ were found on the sun-exposed side of the stem and below thin phellem. Therefore, photoinhibition was partly responsible for the reduction in $F_v/F_m$. The photochemical efficiency of PS2 recovered in late April about a month before the trees got leaves. In the laboratory, $F_v/F_m$ recovered within about a week under low irradiance at 20 °C. Rapid recovery of photochemical efficiency of PS2 in the bark may be important to reduce respiratory loss of $CO_2$ from the stem before the trees get leaves.

*Additional key words: chlorophyll fluorescence induction; irradiance; oxygen evolution; phellem; photosystem 2; poplar; quantum yield; seasonal course; tree age.*

Introduction

The bark of many trees has photosynthetically active cells beneath the cork cambium. The chlorophyll (Chl) content per unit bark area can be as high as in leaves (Pearson and Lawrence 1958, Solhaug et al. 1995). In *P. tremula* the bark contains 17-40% of the whole tree Chl (Kharouk et al. 1995). Although net photosynthetic rate in the bark is negative or close to zero (Kharouk et al. 1995, Nilsen 1995), the capacity for gross photosynthesis may be high (Solhaug et al. 1995). Bark photosynthesis probably has an ecological function in reducing CO$_2$-loss from stem respiration (Köller 1973, Foote and Schaedle 1976), and it may be especially important when deciduous trees have lost their leaves during the cold season (Foote and Schaedle 1978) or when tropical trees have lost their leaves during periods of drought (Muthuchelian 1992).

A low Chl $a/b$ ratio in bark cells (Larcher et al. 1988, Muthuchelian 1992, Solhaug et al. 1995) indicates shade adaptation of photosynthesis in the bark (Lichtenhaler et
at. 1981, Anderson 1986). This may be a result of shading by leaves and by the phellem outside the photosynthetically active cells in the bark. In P. tremula a large fraction of the bark is often covered by thin phellem that may transmit 35-55 % of incident irradiation (Kharous et al. 1992, Solhaug et al. 1995). When the trees have lost their leaves, photosynthetically active cells in the bark of P. tremula may therefore receive high irradiances. Exposure to high irradiances especially at low temperatures often results in photoinhibition (Ogren et al. 1984, Strand and Oquist 1985, Huner et al. 1993).

Photoinhibition is an irradiance dependent reduction of photosynthetic efficiency. Photochemical efficiency of PS2 can be measured by the Chl a fluorescence ratio $F_v/F_m$, and this ratio is often used as an estimate of the degree of photoinhibition. However, factors other than high irradiance, such as heat and frost, may cause reduced $F_v/F_m$ values (Havaux 1992, Robberecht and Juntila 1992, Ranney and Peet 1994). In this study the seasonal variation in $F_v/F_m$ in bark from P. tremula exposed to different irradiances was measured using Chl fluorescence. In addition, the capacity for gross photosynthesis ($P_G$) was estimated by measuring $O_2$ production from bark disks at high $CO_2$ concentrations.

Materials and methods

Trees were selected from two stands, one with 10-15 year old trees and another with 30-40 years old trees, in Ås (59°30'N, 10°47'E).

Chl a fluorescence was measured with a portable fluorometer (Plant Efficiency Analyser, PEA, Hansatech, UK). Stems were taken into the laboratory and fluorescence was measured within 2 h. Bark sections of about 2 × 5 cm and about 0.5 cm thick were cut from the stem with a knife. Most of the phellem was carefully scraped off with a scalpel before dark adaption for 15 min in a standard leaf clip. Fluorescence induction curves of 5 s duration were recorded during irradiation with 1500 $\mu$mol(photon) m$^{-2}$ s$^{-1}$ from light emitting diodes. Recovery of $F_v/F_m$ was studied by placing the lower end of 1 m long stem sections in water in the laboratory. The stems were covered with transparent plastic, and the photon fluence rate (PFR) was about 10 $\mu$mol(photon) m$^{-2}$ s$^{-1}$ and temperature was about 20 °C. Fluorescence was measured after about one and two weeks.

Photosynthetic $O_2$ evolution was measured according to Solhaug et al. (1995) on bark disks with intact phellem.

Results and discussion

Seasonal variation in $F_v/F_m$: There was a rapid decrease in $F_v/F_m$ in early October 1992 at the same time as the trees lost their leaves. $F_v/F_m$ stayed low between 0.4 and 0.6 until it rapidly increased to values above 0.8 during a warm period in late April (Fig. 1). However, the winter 1992/93 was relatively mild, and next year in February 1994 after a cold period $F_v/F_m$ values lower than 0.2 were measured. At that time,