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BRIEF COMMUNICATION

Chlorophyll fluorescence temperature curves of spruce needles from different whorls of the tree

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Abstract

The fluorescence temperature curves of one year old needles from upper whorls of spruce tree had an expressively higher high-temperature fluorescence peak (above 60 °C) than the needles from bottom whorls. These whorles were less irradiated and their needles had a lower chlorophyll *a/b* ratio than those from the upper whorls.

Additional key words: canopy gradient of irradiance; *Picea abies*.

The fluorescence temperature curve (FTC) is the temperature dependence of the chlorophyll (Chl) fluorescence intensity monitored during linear heating of leaves or chloroplasts. The temperature threshold of the first fluorescence increase or the temperature of the first maximum in FTC (M1) is frequently used as an indicator of the photosystem 2 (PS2) functional thermostability (Armond *et al.* 1978, Havaux 1993). Further heating above the temperature of M1 leads to the appearance of a second fluorescence rise with or without subsequent decrease (M2 peak or M2 region). The M2 of FTC has been detected at temperature range of 53-65 °C (*e.g.*, Downton and Berry 1982, Kuropatwa *et al.* 1992, Ilík *et al.* 1995a). A correlation between increasing Chl *a/b* ratio of the samples and pronounced height of the M2 peak was firstly reported by Downton and Berry (1982). A general acceptability of this result was questioned by Mannan *et al.* (1986) who had observed miscellaneous relative M2 height in leaves from different species with a similar Chl *a/b* ratio. However, recently published FTCs measured with spruce needles grown and also acclimated to different irradiances (Špunda *et al.* 1993) and the measurements

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on greening barley leaves (Ilík *et al.* 1995a) support the connection of Chl *a/b* ratio and M2 FTC height. We studied the relative FTC parameter and investigated whether this might reflect the vertical position of needles in the spruce tree.

The measurements were done with one year old needles taken from four whorls selected successively along the vertical direction of a 35 years old Norway spruce [*Picea abies* (L.) Karst.] (The Beskydy Mountains, Northern Moravia, Czech Republic) in June 1993. The needles were collected at 07:00 h and transported to laboratory in darkness, moistured, and kept at temperatures near to 5 °C. Mean values of the FTC parameter M1/F(T30) (fluorescence intensity at the M1 peak to the intensity at 30 °C), reflecting a possible inhibition of the PS2 photochemistry, were between 2 and 2.5. This indicated that the needles were not under acute stress (see Nauš *et al.* 1992b). Therefore, the above parameters expressed probably the long-time acclimation of needles. Photosynthetically active radiation at the levels of individual whorls was measured using quantum sensor *LI-S190* (*Li-Cor*, USA) on a sunny day. The Chl *a/b* ratio was determined spectrophotometrically in 80 % acetone (Lichtenthaler 1987). The FTCs were measured with a laboratory-made spectrofluorimeter using a computer-driven linear heating (Nauš *et al.* 1992a). The excised needles were immersed in distilled water and heated at the rate of 0.06 °C s^{-1} up to 75 °C. Weak actinic irradiance (about 6 μmol m^{-2} s^{-1}) of 436 nm with 15 nm spectral halfwidth was used for Chl fluorescence excitation. The fluorescence intensity was detected from adaxial site of three needles at 685 nm (spectral halfwidth of 4 nm). The FTC measurements were started at the steady state fluorescence conditions after 4 min of irradiation.

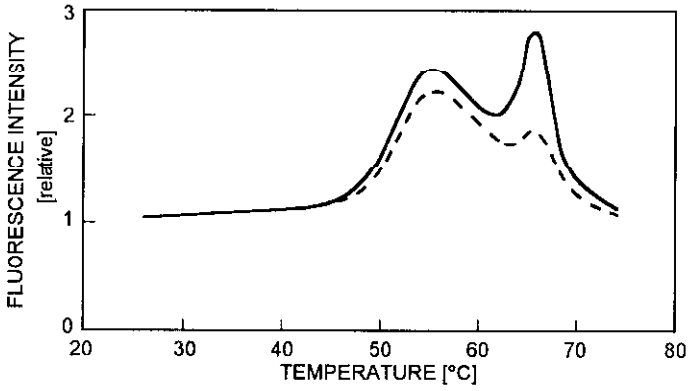

Fig. 1 Typical FTCs of needles from the upper whorls (*full line*) and from the bottom whorls (*dashed line*) of the spruce tree. The curves are normalized for the fluorescence intensity at 30 °C.

The FTC of needles from the upper whorls, exposed to direct sunlight, had a considerably higher M2 part of FTC (60-70 °C) than those from the bottom whorls (Fig. 1). The M2 part was characterized by a peak followed by an abrupt decline, while the FTCs of barley leaves and especially of greening leaves have an M2 region with a slight or even missing decrease (Nauš *et al.* 1992a, Ilík *et al.* 1995a,b). The relative height of the M2 peak was evaluated as the M2/F(T30) ratio (a similar characteristic as for the M1 peak). In needles the M2/F(T30) ratio rose with increasing height of the whorl from 1.6 (bottom whorl) to about 2.8 (top whorl) (Fig.

2*A*). The increasing tendency of the parameter correlated with the vertical irradiance profile (Fig. 2*B*) and with the increasing Chl *a/b* ratio (Fig. 2*C*) along the rising whorl height. The adaptation of leaves to high irradiance leads to an increase of the Chl *a/b* ratio (cf. Anderson *et al.* 1988, Liang *et al.* 1995) which probably reflects a decreasing content of light-harvesting complexes (LHC) (Chow *et al.* 1990, Melis 1991). Our results indicated that the relative height of the M2 FTC part was connected with the Chl *a/b* ratio (see above) and thus with the relative LHC content in thylakoid membranes (Ilík *et al.* 1995a). However, considering the results of Mannan *et al.* (1986) this connection is valid only for differences found within one species.

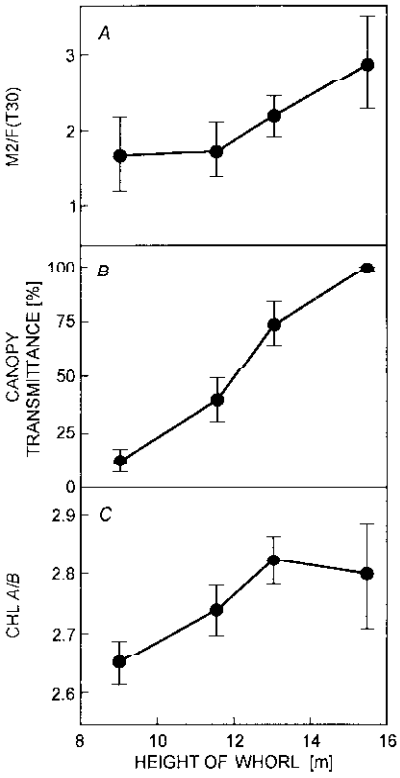

Fig. 2. The M2/F(T30) parameter of FTC (*A*), chlorophyll (Chl) *a/b* (*C*) ratios of spruce needles in the selected whorls of the spruce tree, and relative canopy transmittance at the levels of these whorls (*B*; the highest selected whorl = 100 %). The height of the whorls is the height above the ground level. n = 5-10, ±SD. M2/F(T30) = fluorescence intensity at the M2 FTC peak to the intensity at 30 °C.

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