Inhibition of Photosystems I and II in Chilling-Sensitive and Chilling-Tolerant Plants under Light and Low-Temperature Stress

Carina Barth and G. Heinrich Krause*

Institute of Plant Biochemistry, Heinrich Heine University Düsseldorf
Universitätsstr. 1, D-40225 Düsseldorf, Germany.
Fax: +49–211–81–13706. E-mail: ghkrause@uni-duesseldorf.de

* Author for correspondence and reprint requests

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The responses of photosystems (PS) I and II to light stress at 4 °C and 20 °C were studied in leaf discs from three chilling-sensitive plant species, *Cucumis sativus*, *Cucurbita maxima* and *Nicotiana tabacum*, and in the chilling-tolerant *Spinacia oleracea*. The chilling-sensitive plants were grown at 24 °C under 80–120 μmol photons m^{-2} s^{-1} (*Cucumis* and *Cucurbita*) or 30 μmol photons m^{-2} s^{-1} (*Nicotiana*). *Spinacia* was cultivated outdoors during winter and early spring. The P700 absorbance change around 820 nm served as a relative measure of PSI activity. The potential efficiency of PSII was determined in dark-adapted leaf discs by means of the ratio of variable to maximum chlorophyll (Chl) *a* fluorescence emission (F_V/F_M). In *Cucurbita*, *Nicotiana* and *Spinacia*, PSI was not or only slightly inhibited by 2 h illumination with 200 μmol m^{-2} s^{-1} at 4 °C or with 2000 μmol m^{-2} s^{-1} at 20 °C. In leaves of *Cucurbita* and *Nicotiana*, exposure to 2000 μmol photons m^{-2} s^{-1} at 4 °C resulted in a decline in PSI activity and potential PSII efficiency approximately to the same extent (about 50% within 2 h). In contrast, in *Cucumis*, both moderate and high light at low temperature caused a PSI inhibition that proceeded considerably faster than the decline in PSII efficiency. Such preferential photoinhibition of PSI was not observed in the other three species tested. In *Spinacia*, a lower susceptibility of PSI and PSII to photoinhibition at 4 °C was associated with a faster de-epoxidation kinetics of violaxanthin, as compared to the three chilling-sensitive species. In addition, leaves of *Spinacia* were characterized by a significantly larger pool of xanthophyll-cycle pigments and a higher content of β-carotene based on Chl *a*+*b*. When leaves of *Cucurbita* were preincubated with methylviologen, which catalyzes formation of superoxide anion radicals at the acceptor side of PSI, the decline in potential PSII efficiency under 2000 μmol photons m^{-2} s^{-1} at 20 °C and 4 °C was strongly enhanced, whereas the P700 signal was less affected. Our data demonstrate that in the species tested, PSI may be inhibited *in vivo* besides PSII under light stress, but preferential photoinhibition of PSI is not a general phenomenon in chilling-sensitive plants. At low temperatures, a reduced function of the xanthophyll cycle and of the antioxidative scavenging system might account for enhanced PSI and PSII inhibition *in vivo*.