Changes in photosynthesis in inbred maize lines with different degrees of chilling tolerance grown at optimum and suboptimum temperatures

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Abstract

The effects of growth temperature on changes in net photosynthetic rate \( P_N \) and the chlorophyll fluorescence induction parameter \( F_v/F_m \) were investigated after cold stress in inbred maize lines with different degrees of cold tolerance. There was no significant difference between lines grown at optimum temperatures of 25/23 and 20/18 °C as regards \( P_N \) and \( F_v/F_m \) determined at the growth temperature, but these parameters were lower for plants grown at a suboptimum temperature of 15/13 °C. After cold treatment, the decrease in \( P_N \) was more pronounced in chilling-sensitive lines. The higher the growth temperature was, the more pronounced decrease occurred in \( P_N \) and \( F_v/F_m \). Thus at low growth temperature both damaging and adaptive processes occur.

_Additional key words: chlorophyll fluorescence; gas exchange; intercellular CO\(_2\) concentration; low temperature stress; stomatal conductance; Zea mays._

Introduction

As is the case for most C\(_4\) plants, maize requires a relatively high temperature if it is to develop well. If growth and development take place at below-optimum temperature, several important life functions suffer inhibition, including the photosynthetic apparatus (Baker _et al._ 1983, Long _et al._ 1983). In maize a reduction in the activities of several enzymes has been described. The most important of these are the enzymes responsible for the C\(_4\) reaction pathway, such as pyruvate P dikinase or phosphoenolpyruvate carboxylase (Long 1983). In various chilling-sensitive plants a reduction in activity has been demonstrated for ribulose-1,5-bisphosphate carboxylase (Brüggemann _et al._ 1992), NADP\(^+\)-malate dehydrogenase (Stamp

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1987a), and phosphofructokinase (Stamp 1987b) as the result of cold stress. In cold-tolerant maize lines the dry matter production and leaf growth rate are generally greater than in the cold-sensitive types. A larger net growth is associated with higher \( P_N \) (Stamp et al. 1993). At low growth temperature an alteration in pigment content and arrangement, and an inhibition of electron flow occur (Csapó et al. 1991). Numerous chlorophyll (Chl) fluorescence induction and CO2 fixation parameters indicate that photoinhibition also plays an important role in cold injury to young maize plants (Janda et al. 1994a, Szalai et al. 1996).

The aim of this study was to evaluate how certain parameters related to photosynthetic activity change as the result of low temperature treatment in maize lines with various degrees of cold tolerance, and whether the growth temperature has any influence on their response to low temperature.

Materials and methods

**Plants:** Inbred maize lines (cold-tolerant Z7 and KW1074; cold-sensitive CM109, Mo17, and Penjalinn) in the 4-leaf stage were used in the experiments. The plants were grown in a Conviron PGR-15 chamber at 25/23, 20/18 or 15/13 °C at PPFD of 250 \( \mu \text{mol m}^{-2} \text{s}^{-1} \) (16/8 h light/dark period), and relative humidity of 75 % in a mixture of loamy soil, Vagasca (humus-containing additive, manufactured by Florasca), and sand (3 : 1 : 1, v : v : v). The cold treatment was carried out in the same chamber.

**Gas exchange measurements:** \( P_N \) was measured with a LI-6400 infrared gas analyser operated with a 6400-02 LED light source (LI-COR, Lincoln, Nebraska, USA) providing 250 \( \mu \text{mol m}^{-2} \text{s}^{-1} \) PPFD. Measurements were carried out at the ambient temperature on the youngest fully developed leaves. The gas exchange parameters were determined using the method described by Caemmerer and Farquhar (1981).

**Chl fluorescence induction parameters** were measured at room temperature after 30 min dark adaptation on the youngest fully developed leaves using a fluorometer of the PAM-2000 type (Walz, Effeltrich, Germany). The saturating irradiance (acting for 8 s) was approx. 5000 \( \mu \text{mol m}^{-2} \text{s}^{-1} \).

**Statistical analysis:** Values represent the means of at least 3-5 measurements; they were evaluated using the t-test method.

**Results**

**Plants grown at optimum temperatures:** In the first experiment, the chilling-tolerant inbred maize lines KW1074 and Z7, and the chilling sensitive CM109, Mo17, and Penjalinn lines (Stamp et al. 1993) were grown at 25/23 or 20/18 °C under identical irradiance. Both growth temperatures can be regarded as optimum for young maize plants. There were no significant differences in \( P_N \) between the lines and between the two growth temperatures (Table 1). As a cold treatment the plants were kept first for