Effect of cold stress on photosynthesis and chlorophyll fluorescence in maize inbred lines and their hybrid during seedling phase and grain-filling period

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Introduction

Hybrid vigor in maize (*Zea mays* L) could be associated with increased stress tolerance. The short-term response to abiotic stresses can be quantified by leaf photosynthesis and chlorophyll fluorescence parameters. The response of a maize hybrid and its two parental inbred lines to short periods of cold stress was studied by quantifying leaf photosynthetic rate and PSII quantum efficiency. The objectives of the research were to address the following questions: (1) Is a hybrid more tolerant to low night temperature than its parental inbred lines? (2) Does the response to low night temperature vary between seeding and grain-filling phases of maize development? (3) Can chlorophyll fluorescence analysis be used as selection criterion for the improvement of cold tolerance in maize?

Materials and Methods

The response of the maize hybrid CG60xMBS1236 and its parental inbred lines to low night temperature was studied in three experiments. Two experiments were conducted in growth chambers during the seedling phase (Seedling Stress I and Seedling Stress II) and one experiment was carried out in a field hydroponic system during the grain-filling period (Grain-filling Stress).

In growth chamber studies, plants were grown at PPFD of 600 μmol m^{-2} s^{-1}, 16/8 h light/dark photoperiod, and 26/20°C day/night temperature. At the 5-leaf (tip) stage, plants were exposed to a 8-h night temperature of either 0, 3, and 15°C for 9 days. In the field hydroponic study, plants were grown in 22.5-L pails filled with Turface (Fig. 1). At 2 week after silking, pails were moved to a controlled-environment room for three consecutive nights with temperature in the range 15-20°C for the control and 0°C for the cold stress treatments.

Fig. 1. Maize hybrid CG60xMBS1236 and its parental inbred lines grown in a field hydroponic system.

Leaf carbon exchange rate (CER), quantum efficiency of PSII (Φ_{PSII}), intrinsic quantum efficiency (Fv'/Fm'), and photochemical quenching (qP) were quantified by using the LI-6400 Portable Photosynthesis System attached with Leaf Chamber Fluorometer (Model 6400-40, LI-COR Inc.). In the Seedling Stress I, measurements were made at 15°C and 600 μmol m^{-2} s^{-1} PPFD. Measurements in the Seedling Stress II and Grain-filling Stress were made outside, with temperatures in the range 22-26°C and at 2000 μmol m^{-2} s^{-1} PPFD.

Results and Discussions

➢ Reductions in leaf CER resulted from low night temperature were generally greater when cold stress was applied for three consecutive nights than a single night (Fig. 2).

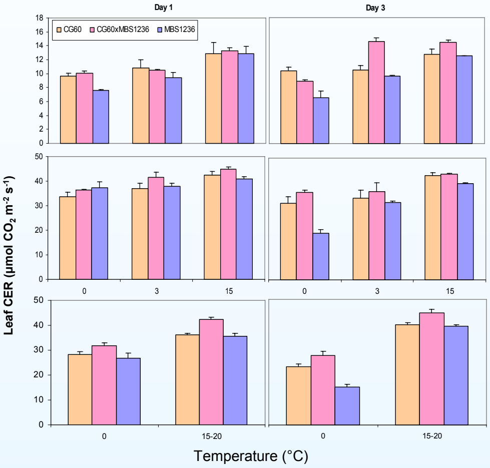

Fig. 2. Leaf CER of maize hybrid CG60xMBS1236 and its parental inbred lines after exposure to 0, 3, and 15°C for a single night and three consecutive nights. Seedling Stress I (Top), Seedling Stress II (Center), and Grain-filling Stress (Bottom).

➢ Reductions in leaf CER after the cold-night treatments were similar for the hybrid and the inbred line CG60, but reductions were 20-60% greater for the inbred line MBS1236 (Table 1 and Fig. 3a). Also, the decline in leaf CER in plant exposed to a 3-°C night vs. a 0-°C night was about two times greater for MBS1236 than for the hybrid and CG60 (Table 1).

Table 1. Leaf CER and reductions of leaf CER in maize hybrid CG60xMBS1236 and its parental inbred lines after three consecutive nights of low temperature stress.

Treatment	CG60	MBS1236	CG60xMBS1236
	Leaf CER (μmol CO_2 m^{-2} s^{-1}) or reduction (%)		
Seedling Stress I			
Control (15°C)	**12.8**	**12.5**	**14.5**
0°C	19.0b	47.7a	38.8ab
3°C	18.0a	22.9a	0.1b
Seedling Stress II			
Control (15°C)	**42.8**	**39.6**	**43.3**
0°C	26.3b	51.3a	16.9b
3°C	21.7	19.9	16.0
Grain-filling Stress			
Control (15-20°C)	**40.0**	**39.4**	**44.8**
0°C	42.3b	61.5a	38.6b

➢ Reductions in leaf CER due to 0-°C treatments were greater in the Grain-filling Stress experiment than in the Seedling Stress II experiment, but relative differences in the reductions among the hybrid and its parental inbred lines were similar for both phases of development (Table 1).

➢ In Seedling stress I, changes in leaf CER at the end of nine consecutive nights of low temperature treatments for the hybrid and its parental inbred lines were associated with changes in the chlorophyll fluorescence parameters Φ_{PSII}, Fv'/Fm', and qP (Fig. 3).

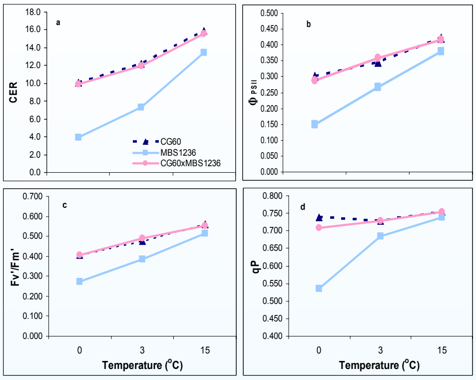

Fig. 3. Effect of low night temperature on leaf CER (a) and fluorescence parameters, Φ_{PSII} (b), Fv'/Fm' (c), and qP (d), of maize hybrid CG60xMBS1236 and its parental inbred lines in Seedling Stress I.

➢ The association between the changes of leaf CER and chlorophyll fluorescence parameters suggested that the hybrid and the inbred CG60 could maintain higher quantum efficiency (Φ_{PSII}) than the inbred MBS1236 at low night temperature. The higher Φ_{PSII} in the hybrid and the inbred CG60 could be due to, in part, higher efficiency of open PSII reaction centers (Fv'/Fm').

➢ The relatively large reduction in leaf CER and the change in leaf color after nine consecutive nights at 0°C in the inbred line MBS1236 (Fig. 4) were associated with a large decrease in photochemical quenching (qP), which indicates a large proportion of PSII reaction centers that are close.

Fig. 3. Maize seedlings and leaves exposed to 0°C for nine consecutive nights. The inbred line CG60, the hybrid CG60×MBS1236, and the inbred line MBS1236 are arranged from left to right.

Conclusions

- ❑ The maize hybrid CG60×MBS1236 is not more tolerant to cold stress than its parental inbred lines CG60. The inbred line MBS1236 is less tolerant to cold stress than either CG60 or the hybrid.
- ❑ The relative response of leaf photosynthesis to low night temperature of the hybrid and its parental inbred lines did not vary between the seeding phase and the grain-filling period.
- ❑ Reductions in leaf CER in MBS1236 exposed to night temperatures of 0°C were associated with a decrease in photochemical quenching.