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Effects of drought on thermal stability of photosynthetic apparatus in bread wheat and in *Aegilops* species originating from various habitats

Sándor Dulai[1]*, István Molnár[2], Judit Prónay[1], Mariann Marschall[1], Ágota Csernák[1], Réka Tarnai[1], Márta Molnár-Láng[2]

[1]Department of Plant Physiology, Eszterházy College, Eger, Hungary, [2]Agricultural Research Institute, Hungarian Academy of Sciences, Martonvásár, Hungary

ABSTRACT The responses of thermal stability of photosystem II to drought induced by dessication in soil pots were examined in two wheat (*Triticum aestivum* L.) cultivars and in *Aegilops* genotypes originating from habitats with different annual rainfalls and daily temperatures. The three days drought treatment did not effect a considerable water loss in leaves and parallel with this a significant heat-tolerance increase of PS II determined on the basis of breakpoints (T_c, T_p) of the temperature dependence of steady-state fluorescence level (F_s *vs. T* curves) at 1000 μE m^{-2} s^{-1} actinic light (AL) intensity was not observable. Higher water deficit (RWC<75%, 10-14 day drought treatment) resulted in a significant increase in thermal stability, for wheat and for several *Aegilops* genotypes. In a dark-adapted state the critical values of the F_0 *vs. T* curves did not shift towards significantly higher temperatures with an increase in water deficit. The results indicate that some *Aegilops* genotypes originating from arid habitats have better heat tolerance than wheat during drought, making them appropriate for improving the heat tolerance of wheat enabling it to survive the dry and hot periods in the field.

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KEY WORDS

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photosystem II
water deficit
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Aegilops species with good tolerance to some major abiotic stress factors are closely related to wheat (Van Slageren 1994; Molnár et al. 2004). Especially the tetraploide goat grass (*Aegilops biuncialis* L., 2n = 4x = 28, $U^bU^bM^bM^b$) has a good drought tolerance, which makes it suitable to improve the drought tolerance of wheat (Molnár et al. 2004). In addition, diploide goat grasses, such as *Ae. tauschii* Coss. (DD), *Ae. bicornis* (S^bS^b) and *Ae. speltoides* Tausch. (SS) have some good advantages. As the B and D genome donor of wheat are the *Ae. speltoides* and *Ae. tauschii* genotypes, the chromosome mediated gene transfer from these species to hexaploide wheat is easier than from *Ae. biuncialis*.

Drought and heat are important biomass-limiting stress factors (Araus et al. 2002) in the field causing the suppression of cultivated plants in growth and in crop production (Blum et al. 1997). The heat sensitivity of plants is closely connected to the thermal stability of PS II. It is more or less clear that the thermal tolerance of the photosynthetic apparatus in some higher plants is influenced by other stress factors like light (Havaux and Tardy 1996; Molnár et al. 1998), and by water deficit in a desiccation tolerant moss (Dulai et al. 2004). The study of these problems is further justified by the fact that under natural conditions high light intensity, heat stress and water deficit occur in combination with each other: the effect of the three stress factors needs to be tolerated at the same time. This short study reports on the effects of decreasing water content on the thermal stability of the photosynthetic apparatus at moderately high light intensity in several *Aegilops* genotypes to indicate that some of them have better heat tolerance than wheat during drought, making them suitable for improving the heat tolerance of wheat by intergeneric crossing, enabling it to survive the dry and hot periods in the field.

Materials and Methods

All experiments were performed on intact leaves or leaf segments of *Triticum aestivum* L. and of *Aegilops* sp. Seeds were germinated under laboratory conditions. After germination, these plants were grown in 1.5 kg soil pots in an unheated greenhouse for 5 weeks under natural sunlight. The water deficit was induced by withholding the water supply in the soil. The water status of the plants was traced by determining the relative water content (RWC).

The responses of the *in vivo* chlorophyll-a fluorescence to heat were measured in dark-adapted leaves with a pulse amplitude modulation fluorometer (PAM 101-103, Walz, Effeltrich, Germany) as described by Dulai et al. (1998). To determine the breakpoints (T_c, and T_p) of the F_0 *vs. T* or F_s *vs. T* curves the heat induction of fluorescence method was applied as described by Schreiber and Berry (1977).

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*Corresponding author. E-mail: ds@ektf.hu

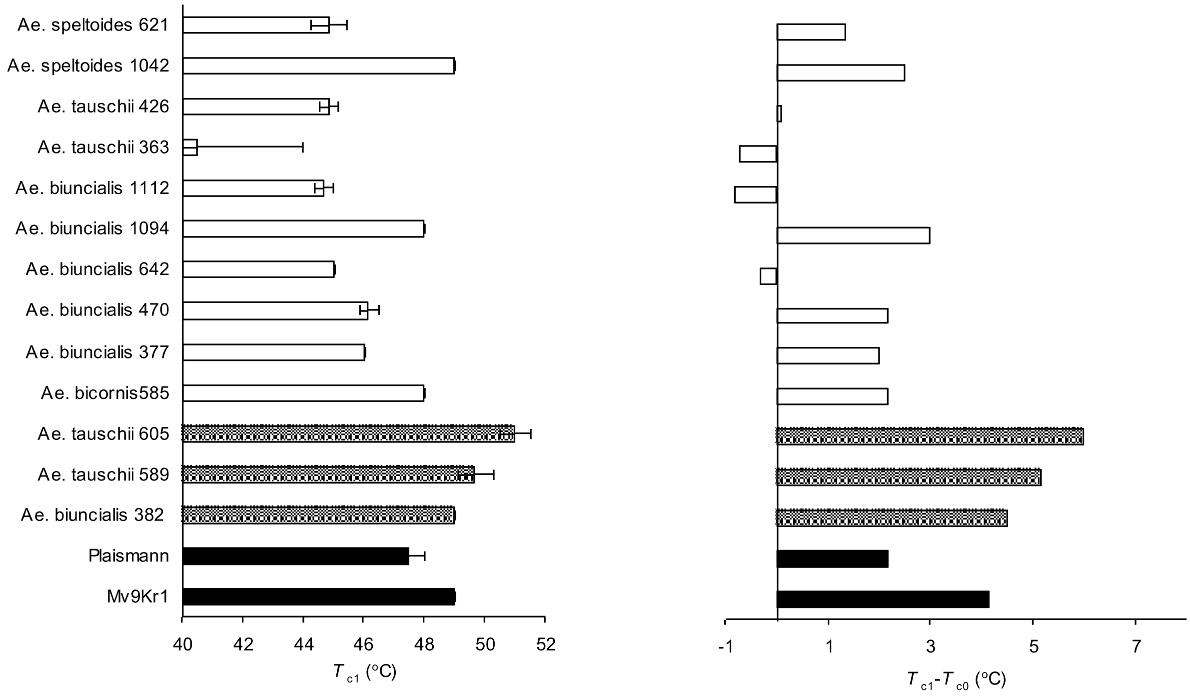

Figure 1. Effects of water deficit on the breakpoints (T_{c1}) of the F_s *vs. T* curves at 1000 µmol m^{-2} s^{-1} actinic light (AL) intensity measured at the end of the dry period (on the left) and the phenotypic plasticity to heat (T_{c1-} T_{c0}, on the right) for wheat and for *Aegilops* lines. (T_{c0}), T_c values of non-stressed plants; (T_{c1}), T_c values measured at the end of the dry period.

Results and Discussion

The sensitivity of plants to heat stress is closely connected to the thermal stability of PSII, which is well characterized by the critical values of the temperature dependence of the initial fluorescence level (F_0) of dark-adapted leaves (Schreiber and Berry 1977). The heat tolerance of PSII in wheat and in *Aegilops* genotypes determined on the basis of the F_0 *vs. T* curves (practically in darkness) was not sufficient for tolerating such high temperatures that are peculiar to their original habitats (not shown by data) coupled with high irradiation and drought. Similarly to F_0, the breakpoints (T_c, T_p) of temperature dependence of steady state fluorescence (F_s) – according to recent results – appropriately show the thermal stability of samples with a steady-state photosynthesis level (Molnár et al. 1998; Dulai et al. 2004). In connection with this, T_c values of F_s *vs.T* curves measured at moderately high AL intensity (1000 µE m^{-2} s^{-1}) shifted towards significantly higher temperatures (42-45°C), indicating a higher thermal tolerance of PSII in wheat cultivars and in goat grasses (not shown by data).

Although during drought the relative water content and the activity of some photosynthetic processes decrease, there are observations to the effect that in higher plants the slow dehydration of removed leaves resulted in an increase of the thermal stability of PS II (Havaux 1992). To select the promising *Aegilops* genotypes with high tolerance to heat during drought, the thermal stability of PSII was examined. The three-day drought treatment did not effect a considerable water loss in leaves and, parallel with this, a significant heat-tolerance increase of PS II was not observable. Whereas heat sensitivity during the drought increased in three *Aegilops* genotypes, as a result of severe water deficit (RWC<75%), in wheat cultivars and in most goat grasses with steady-state photosynthesis at 1000 µmol m^{-2} s^{-1} AL intensity the critical values of the F_s *vs. T* curves shifted significantly higher, compared to the unstressed plants (Fig. 1). This enhanced thermal stability was more or less also manifested by the temperature dependence of the effective quantum yield of PSII (not shown by data). These phenotypic plasticity changes (Fig. 1) to heat were most remarkable for three goat grasses originating from arid habitats (*Ae. biuncialis* MvGB 382, *Ae. tauschii* MvGB 589 and *Ae. tauschii* MvGB 605). These properties make them a good candidate for improving the heat and drought tolerance of wheat by intergeneric crossing to enable it to effectively survive the forecasted dry and hot periods in fields of central Europe.

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