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ARTICLE

Changes in photosynthetic performance and ABA levels under osmotic stress in drought tolerant and sensitive wheat genotypes

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ABSTRACT We investigated the effect of osmotic stress induced by 400 mOsm PEG 6000 on the photosynthetic parameters and the abscisic acid (ABA) levels in drought tolerant (*Triticum aestivum* L. cv. MV Emese) and sensitive (cv. GK Élet) wheat cultivars in seedling stage. Our aim was to find fast and sensitive laboratory methods for screening drought sensitivity of the genotypes. The water potential (Ψw) values, net CO_2 assimilation, chlorophyll *a* (chla) fluorescence and ABA levels in leaves and roots were determined as a function of increasing osmotic stress. Although the decline of Ψw was more significant in the leaves of the sensitive cultivar (cv. Élet), the effect of water stress on the PSII photochemistry was not more pronounced. The ABA levels increased earlier, from day 9 under osmotic stress in the sensitive cultivar, but the hormone contents of the leaves were higher in the tolerant cv. MV Emese. This suggests that the accumulation of the stress hormone, ABA is a first line of defence to osmotic stress.
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KEY WORDS

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Among the environmental stresses, drought stress is one of the most adverse factors for plant growth and productivity. Germination in solution with high osmotic potential (e.g. mannitol, PEG) is one of the most important laboratory methods suggested for screening drought tolerance of crop plants. Good laboratory tests for screening genotypes have to show significant correlation with drought resistance (Grzesiak et al. 2003; Hajiboland and Hasani, 2007). Since photosynthesis is one of the main metabolic processes determining crop production, chlorophyll fluorescence was used as an effective tool for monitoring the function of the photosynthetic apparatus in response to water stress (Flexas et al. 2002; Fracheboud and Leipner 2003). Since water stress resulted in a decrease of CO_2 assimilation rates due to reduced stomatal conductance, reduction of biomass production proved to be very sensitive to water deficit. The plant hormone abscisic acid (ABA) is also produced under water deficit, and plays an important role in response and tolerance to dehydration (Zhang et al. 2006; Šafránková et al. 2007), such as regulation of plant water status through stomatal conductance, control of leaf and root growth as well as the induction of genes that encode enzymes and other proteins involved in cellular dehydration tolerance (Zhu 2002).

Materials and Methods

Two Hungarian wheat cultivars, *Triticum aestivum* L. cv. MV Emese, a drought tolerant and cv. GK Élet, a drought sensitive genotype were investigated under control and osmotic stress conditions. Plants were grown in hydroponic culture, and the osmotic stress was induced by polyethylene glycol treatment (PEG 6000). The increased amount of PEG 6000 reaching the final value of 400 mOsm (-0.976 MPa) was applied gradually in the culture media of one-week-old plants as it was published earlier (Erdei et al. 2002).

Leaf water potential (Ψ_w) was determined by pressure chamber (PMS Instrument Co.). Photosynthetic activity measurements were carried out using a portable photosynthesis system (LI-6400, Lincoln, Nebrasca-USA). After 20 minutes of dark adaptation the maximal efficiency of PS II photochemistry (F_v/F_m) was determined. The photochemical quenching (qP), non photochemical quenching (NPQ), the actual quantum yield of PSII electron transport (Φ_{PSII}), electron transport rate (ETR) and net photosynthetic rate (P_N) were determined in light adapted leaves exposed to 300 µmol $m^{-2}s^{-1}$ light intensity. The CO_2 assimilation rate was measured together with the chlorophyll fluorescence parameters after 20 minutes of light adaptation. Light response curves were generated by varying light intensities (50, 150, 300, 400, 500, 700, 1200, 1500 µmol m^{-2} s^{-1}) after 10 minutes of dark adaptation on the 16th day after anthesis.

For the determination of ABA, samples were purified, quantified and recovery was determined as described by Yang et al. (2003). ABA was analysed by indirect enzyme-linked assay (ELISA) using Phytodetek Assay Kit (Idetek) supplied

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by Sigma Ltd. Colour absorbancy following reaction with the substrate was read at 405 nm using a plate auto reader (Dynatech MR 4000). Percentage binding was calculated using established procedures (Weiler et al. 1981).

Results and Discussion

Response of two wheat cultivars to 400 mOsm PEG 6000 exposure was measured for 21 days after germination. The water potential values did not change significantly under stress conditions during 21 days in the tolerant cultivar, MV Emese. In contrast, in the sensitive GK Élet significant differences were observed between the treatments. The Ψ_w values declined from the 13th day under osmotic stress and they remained lower than in the control plants until the 21st day. The osmotic stress affected the water status of the sensitive genotype more significantly.

The values of maximal efficiency of PS II photochemistry (F_v/F_m) in the dark adapted leaves remained around 0.8 until the 21st day after germination in both varieties. The actual quantum yield of PSII electron transport (Φ_{PSII}), qP or the NPQ values did not change considerably in light adapted leaves of the genotypes up to the first 13 or 11 days, respectively. In the tolerant cultivar, MV Emese Φ_{PSII} and qP decreased significantly from the 15th day and NPQ increased from the 12th day, while in the sensitive GK Élet Φ_{PSII} and qP decreased only on the last, 21st day. However, in the sensitive genotype the reduction in Φ_{PSII} and qP was more pronounced to the end of the experiment.

The net photosynthetic rate (P_N) decreased under osmotic stress in both genotypes. A significant decline was observed in P_N of cv. MV Emese and that of cv. GK Élet from the 13th and from the 15th , respectively, and at the 21st day the sensitive cultivar did not assimilate CO_2 at all.

The changes in Φ_{PSII}, qP and NPQ as a function of photon flux density (PFD) were determined 16 days after germination. In the sensitive cultivar, GK Élet no significant differences were found in the Φ_{PSII} and qP values at any PFDs between control and stressed plants, the NPQ values increased slightly and this rise proved to be significant between 50 and 400 µmol $m^{-2}s^{-1}$. In contrast to the drought sensitive genotype, the Φ_{PSII}, qP and P_N values decreased with increasing PFDs at a much higher rate in the tolerant cultivar MV Emese under osmotic stress. These results suggest that osmotic stress did not result in neither sensitive nor tolerant cultivar-specific modifications in PSII photochemistry and in CO_2 assimilation in the dark- or light-adapted first leaves of wheat seedlings.

Abscisic acid content of first, second and third leaves and roots were determined. In the first and second leaves of the tolerant genotype, MV Emese, the hormone levels increased already in the 11th day and after a maximum they tended to decline for the 21st day, but the hormone contents of the leaves remained enhanced up to the end of the experiment under osmotic stress. In the roots ABA accumulation began from the 13th day, and increased up to the 21th day. Effective accumulation of ABA in the leaves of the tolerant cultivar after PEG treatment can be explained by the fast transport of the hormone to the leaves, but ABA synthesis in the leaves cannot also be excluded. In the first leaves of GK Élet the ABA levels were significantly higher under osmotic stress from the 9th day, earlier than in the tolerant genotype. The increase in ABA was observed from the 11th day in the second leaves, and at the 21st day in the third leaves. In the roots of GK Élet the hormone levels increased under osmotic stress from the 13th day, as in MV Emese, and in the sensitive cultivar the measured concentration values were higher than in the tolerant genotype. This may suggest that transport of ABA from roots to leaves could be less efficient in the sensitive variety.

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