Inadequate water supply may impose severe abiotic stress on plants. Its consequences impair the growth of crop plants and decrease yield. The extent of damage depends on both severity and duration of drought stress (Araus et al. 2002; Bartels and Souer 2004). Tolerance to this environmental condition is complex and may be activated by several different signaling pathways. A well-characterized effector function activated by these signaling steps is an increase of stomatal resistance due to fast closure. Other potential responses include changes of root growth and accumulation of osmolytes (Parsons and Howe 1984; Bartels and Nelson 1994; Bohnert, Nelson and Jensen 1995). The photosynthetic apparatus is relatively well protected, but may get damaged if the stress is severe or long lasting. This study investigates drought-sensitive Cappelle Desprez, GK Élet and drought-tolerant Plainsman V, Mv Emese winter wheat (*Triticum aestivum*) genotypes subjected to water deprivation at anthesis. Gas exchange measurements showed depletion of internal CO$_2$ in the leaves of the tolerant but not in the sensitive cultivars. Tolerant genotypes had lower stomatal density and significantly smaller leaves than the sensitive ones. The potential contribution of these traits to drought tolerance is discussed.

**Materials and Methods**

Plants were grown in a soil-sand-peat mixture (3:1:1, v/v/v) after 7 weeks of vernalisation at a temperature of 2°C, in phytotron chambers (Conviron, Winnipeg, Canada) using the spring climatic programme T1 (Tischner et al. 1997). Full deprivation of water supply was started 3 days prior to anthesis and was applied twice (until the volumetric water content of the soil dropped in both treatments to 10%) with one watering (150 mL) in between. Along with the treated plants a control group was grown with normal water supply.

The whole experiment was repeated 2 times in 2010. Gas exchange parameters were detected by a Li-Cor 6400 Portable Photosynthesis System instrument. This equipment records rate of photosynthesis, stomatal conductance, transpirational rate and intercellular CO$_2$ concentration (Ci) among others.

For morphological studies leaves were collected after re-irrigation following the second stress treatment, cleared overnight in a solution containing 41% ethanol, 21% chloroform, 17% lactic acid, 21% phenol and 3.63 M chloral hydrate, washed, and stored in 50% ethanol. The cleared epidermal peels were manually dissected from various parts of the tip, middle and base of the flag leaves, flattened in distilled water, mounted on microscope slides in 50% glycerol and examined with an Olympus B51 microscope (Olympus Corp., Tokyo Japan). Determination of the leaf area and stomatal density was performed using a CellP image analysis system (Olympus, Tokyo, Japan).

**Results and Discussion**

Of the data recorded by the Li-Cor 6400 instrument here we present the Ci values measured. In case of the two tolerant genotypes (cvs. Plainsman and Mv Emese) a decrease in the Ci rate could be observed at the end of the first stress treatment. This decline of Ci did not occur in the sensitive cultivars (cvs. GK Élet, Cappelle Desprez) (Fig. 1).

The contrasting values of Ci at the end of the first drought period may be explained by faster stomatal closure and sustained photosynthetic activity of the drought-tolerant plants, which depletes the leaf interior of CO$_2$. Flag leaves were fully
expanded at the time of anthesis, thus water withholding had no effect either on the size of the leaves or on stomatal density (SD; data not shown). The area of flag leaves was significantly smaller in the drought tolerant cultivars (Table 1). SD was significantly higher on the adaxial surface of the flag leaves in all genotypes (Table 1). The total number of stomata per leaf was the lowest in drought tolerant Plainsman V and the highest in drought sensitive Cappelle Desprez.

These features of physiological response and leaf morphology may contribute to drought hardiness of the tolerant cultivars in comparison with the sensitive ones.

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Table 1. Flag leaf areas, stomatal densities of adaxial and abaxial leaf surfaces and the total number of stomata per leaf of the drought tolerant Plainsman V and Mv Emese and, drought sensitive GK Élet and Cappelle Desprez wheat cultivars.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Leaf area (mm²)</th>
<th>SD adaxial (mm⁻²)</th>
<th>SD abaxial (mm⁻²)</th>
<th>Stoma/leaf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plainsman V</td>
<td>2551±551</td>
<td>35±3</td>
<td>48±4</td>
<td>209748±39697</td>
</tr>
<tr>
<td>Mv Emese</td>
<td>3928±510</td>
<td>37±1</td>
<td>51±3</td>
<td>335832±52828</td>
</tr>
<tr>
<td>GK Élet</td>
<td>4536±823</td>
<td>41±4</td>
<td>57±5</td>
<td>417826±63977</td>
</tr>
<tr>
<td>Cappelle Desprez</td>
<td>5345±443</td>
<td>41±2</td>
<td>58±2</td>
<td>515503±45671</td>
</tr>
</tbody>
</table>

Within columns, means superscripted by the same letter are not significantly different at the P < 0.01 level of probability.
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References


