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ARTICLE

Changes of photosynthetic parameters in wheat/barley introgression lines during salt stress

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ABSTRACT Salt stress induced photosynthetic responses were investigated in the wheat/barley introgression lines developed in the Agricultural Research Institute, Martonvásár, Hungary, and in different parental wheat and barley *Hordeum vulgare* L. genotypes. An increase in NaCl concentration of the nutrient solution to 200 mmol L^{-1} resulted in a considerable stomatal closure and a decreased net CO_2 assimilation rate (*A*) for wheat genotypes, barley cv. Betzes and 4H Asakaze komugi-Manas addition line while changes of these parameters were less significant for barley cv. Manas and the 7H Asakaze komugi-Manas and 6H Mv9 kr1-Betzes-Seneca addition lines. These preliminary results suggest that the 7H Akom-Manas addition line may be a good candidate for improving the salt tolerance of wheat in the future.
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KEY WORDS

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Salt stress is an important biomass-limiting stress factor in the field causing the suppression of cultivated plants in growth and in crop production (Belkhodja et al. 1999; Dulai et al. 2011). In crop plants several life processes are particularly sensitive to soil and water salinity, since high salt concentration has a three-fold effect: it limits water availability to the roots (osmotic stress); it can cause ionic stress when the salt is taken up by plants; and it also influences nutrient uptake and translocation (Bagci 2003; Siler et al. 2007). The reduction in photosynthesis during salt stress can be attributed to the reduced activity of primary photochemical processes (Kaiser et al. 1983) and the inhibition of carbon-dioxide fixation and assimilation (Siler et al. 2007; Dulai et al. 2011) related to metabolic processes and the diffusion of CO_2 to chloroplasts. Furthermore, the estimation of net assimilation rate might allow for a good discrimination between salt tolerant and non-tolerant cultivars of barley (Belkhodja et al. 1999).

The development of salt tolerant crops bears significant agricultural and economical importance, as soil salinity decreases the yield of cultivated plants. Barley is a potential gene source for wheat improvement, because of its generally good stress tolerance (Molnár et al. 2007). The introgressive hybridization of barley to wheat makes it possible to transfer some useful characteristics of salt tolerance as barley is regarded as being more salt tolerant than bread wheat (Colmer et al. 2005; 2006).

In this paper the photosynthetic responses to salt stress in the parental winter wheat (Mv9kr1, Asakaze komugi) and barley (Manas, Betzes) cultivars were compared with those of 4H, 7H Asekazi komugi-Manas and 6H Mv9kr1-Betzes-Seneca addition lines, in order to indicate whether the introgression lines had better tolerance to salinity than wheat.

Materials and Methods

The salt stress was applied on the wheat/barley introgression lines produced in Martonvásár (Molnár-Láng et al. 2000), together with the parental lines (Table 1). After germination, plants were grown in pots containing 1500 mL volume in half-strength modified Hoagland nutrient solution in growth chambers under normal CO_2 concentration at 20/25°C. Growth light intensity was 200 µmol m^{-2} s^{-1} with a 12/12 photoperiod. The water status of plants was traced by determining the relative water content (RWC).

CO_2 assimilation of intact leaves was measured with an infrared gas analyser (GFS-3000-FL gas exchange system, Walz, Effeltrich, Germany). The net CO_2 assimilation rate (*A*), stomatal conductance (g_s), and intercellular CO_2 concentration (C_i) were calculated in the light saturated state of photosynthesis by using the equations of von Caemmerer and Farquhar (1981).

Results and discussion

In this study the photosynthetic performance of the newly developed wheat-barley introgression lines was examined and compared with those of parental genotypes under 200 mM salt concentration. These examination were encouraged by earlier findings suggesting that barley is regarded as being more salt tolerant than bread wheat (Colmer et al. 2005, 2006).

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Table 1. Values of relative water content (RWC), stomatal conductance (g_s) and net CO_2 assimilation rate (A) for NaCl treated (200 mmol L^{-1}, Stress) and for control plants of similar age grown in nutrient solution without NaCl (Control). Mv9kr1, winter wheat originating from a Martonvásári wheat cultivar; Akom, winter wheat cv. Asekaze komugi; Manas, barley cv. Manas; Betzes, barley cv. Betzes; 4H add, 4H Asakaze komugi-Manas addition line; 7H add, 7H Asakaze komugi-Manas addition line; 6H add, 6H Mv9 kr1-Betzes-Seneca addition line.

Genotypes	Relative water content (RWC)		Stomatal conductance (g_s, mmol m^{-2} s^{-1})		Net CO_2 assimilation rate (A, µmol m^{-2} s^{-1})	
	Control	Stress	Control	Stress	Control	Stress
Mv kr1	94.93±0.24	89.21±1.65	226.56±1.16	117.76±12.04	19.7±1.16	10.17±1.24
Akom	90.09±2.88	84.08±2.93	276.18±9.82	93.26±8.26	16.82±0.62	9.6±1.03
Manas	86.46±3.9	79.15±4.6	187.39±24.18	159.27±6.75	15.8±1.42	13.98±0.85
Betzes	94.79±0.8	81.68±4.18	234.85±5.98	112.71±3.26	20.63±0.29	9.9±0.97
4H add	84.25±1.64	83.45±2.96	299.92±51.86	88.24±8.7	16.99±1.61	11.18±0.43
7H add	93.6±1.38	82.52±0.73	189.81±7.12	132.87±13.35	15.79±1.23	14.35±1.71
6H add	93.68±0.83	86.13±3.62	208.47±9.86	144.67±15.6	15.01±1.51	13.75±0.87

As salt stress not only has an ionic effect but also lead osmotic stress the water balance of plants is changed during salt treatment, as a result of which the RWC of leaves decreases. Except the 4H add salt stress causes a reduction in RWC all of the examined genotypes (Table 1). Parallel with the decrease in water content the initially high stomatal conductance (g_s) decreased significantly in wheat lines, Betzes and 4H add. Although the decrease in g_s was moderate in 6H and 7H add the water content remained at a level similar to the Akom.

As the stomata play an important role in the regulation of transpirational water loss during salt stress, the primary physiological effect of the salinity is the inhibition of photosynthetic CO_2 fixation partly by means of stomatal closure (Centritto et al. 2003). A decreased substantially as g_s fell in Akom, Mv9kr1, Betzes and 4H add at 200 mmol L^{-1} NaCl (Table 1). At this level of salinity, however, A and g_s only decreased slightly in Manas, 6H add and 7 H add. These results indicate that 7 H add like the parental barley cv. Manas, was able to retain its CO_2 fixation rate during salt stress with relatively high g_s. Barley is regarded as being more salt tolerant than bread wheat and the role of 7H addition in modifying the Na^+ and K^+ contents in leaves during salt stress has also been described (Colmer et al. 2006). In connection with this, a previous study has reported that photosynthetic rate was unaffected in a salt resistant common centaury in this salinity range (Siler et al. 2007). Moreover, it is thought that the estimation of net assimilation rate is could be a good tool for discriminating between salt tolerant and non-tolerant cultivars (Belkhodja et al. 1999). It is interesting that 6H add seems also tolerant to the salt stress in spite of the salt sensitivity of its parental barley genotypes (Betzes).

Our results seem to suggest that the newly-developed 7H Akom-Manas addition line is able to maintain at a satisfactory level its photosynthetic activity with a low level of water loss under moderate salt stress. Consequently, the better tolerance of photosynthetic parameters to moderate salinity of parental barley cv. Manas might be manifested in this plant.

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Abbreviations used

A, net CO_2 assimilation rate; Akom, Asekaze komugi; 4H add, 4H Asakaze komugi-Manas addition line; 6H add, 6H Mv9kr1-Betzes-Seneca addition line 7H add, 7H Asakaze komugi-Manas addition line; g_s, stomatal conductance; RWC, relative water content.

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