CONTROL OF WHEAT LEAF GROWTH UNDER SALINE CONDITIONS II. WATER RELATIONS PARAMETERS

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This experiment was carried out to investigate the possible mechanism involved in the turgor stability. For the purpose various water relations parameters were studied. The tissue osmotic pressure was equal to 1.1 MPa and it increased continually throughout the experimental period. The cell wall transpiration tension was found to be equivalent to 0.1 MPa indicating the high values of osmotic pressure of osmotically active solutes present in the cell wall i.e. about 0.6 to 0.7 MPa. Turgor pressure dropped when very high concentrations of NaCl (200 and 250 mol m^{-3}) were applied to the medium. This is presented as evidence that growing leaf cells maintained their turgor pressure in response to the salt stress by taking up the osmotically active solutes present in the cell wall.

INTRODUCTION

According to Lockart growth model (Lockhart, 1965) the growth rate of plant tissue is a function of the turgor pressure and the rheological properties of the cell wall;

$$r = \phi (P - Y) \quad (1)$$

where

r = rate of volumetric growth,
ϕ = cell wall extensibility,
P = turgor pressure, and
Y = yield threshold.

In our experiments (Arif *et al.*, 1992) to study the biophysical parameters of Lockhart model in wheat leaves under saline conditions, the turgor pressure was found to be nearly constant. The constancy of turgor pressure at different growth rates using tissue-averaged methods (Matsuda and Riazi, 1981; Michelena and Boyer, 1982; Matthews *et al.*, 1985) and pressure probe (Pritchard *et al.*, 1987; Rich and Tomos, 1988; Thomas *et al.*, 1989) implies the possible involvement of cell wall solutes in the maintenance of turgor pressure and in the control of growth. Involvement of the solutes, present in cell wall, in water relations has been postulated (Oertli, 1969; Bernstein, 1971; Cosgrove and Cleland, 1983; Clipson *et al.*, 1985). Hence, the study of various other water relations parameters is inevitable.

MATERIALS AND METHODS

Growth of plants: Plants were grown following the method of Arif *et al.* (1992).
Measurement of tissue osmotic pressure: Cell osmotic pressure was not measured directly, instead, it was assumed that osmotic pressure of expressed tissue sap was equivalent to the cell osmotic pressure.

However, the cell sap would be expected to be slightly diluted by the extracellular water during the tissue crushing (Tomos *et al.*, 1984). Osmotic pressure of tissue sap (extracted using the method of Tomos *et al.*, 1984 with minor modifications) was measured using a vapour pressure osmometer, calibrated in mOsm kg^{-1} water using standard solutions (290 and 1000 mOsm kg^{-1}) provided by the manufacture. The values obtained in mOsm kg^{-1} were converted to pressure units (MPa) using the Van't Hoff relationship at 20 °C (Nobel, 1983) i.e. by dividing it with 407 mOsm kg^{-1} MPa^{-1}.

$$\pi_w = \pi - P + P_w \quad (2)$$

Note: P_w is always a negative entity.

RESULTS AND DISCUSSION

To find out the possible reason for the turgor maintenance some water relations parameters were studied. The cell wall transpiration tension was found to be about 0.11 ± 0.04 MPa for the growing region (Table 1). Osmotic pressure of tissue sap was nearly 1.1 MPa for control plants. It increased gradually with time and the increase corresponded to the stress level (Fig. 1). In Figure 1, the results of only two stress levels i.e. 25 and 150 mol m^{-3} NaCl have been presented due to space limits. The turgor pressure in expanding cells of control plants is quite lower than the osmotic pressure even after the abolition of wall transpiration tension. This either suggests a growth-induced water potential gradient from xylem to the cell (Nomani and Boyer, 1989), a wall hydrostatic tension that is independent of transpiration or the presence of osmotically active solutes in the cell wall. The last possibility has been argued by several colleagues in other cases, e.g. non-growing tissue (Leigh and Tomos, 1983), growing tissue (Cosgrove and Cleland, 1983; Clipson *et al.*, 1985; Tomos, 1988).

Table 1. The effect of plant immersion under the hydroponic medium on turgor pressure in epidermal cells of leaf growing zone

Turgor pressure (MPa)		Transpiration tension (MPa)
In the air	Under the medium	
0.45 ± 0.05	0.56 ± 0.09	0.11 ± 0.04

Estimation of cell wall transpiration tension: To measure the cell wall transpiration tension (P_w), the turgor pressure was measured (for each NaCl concentration) in continuously transpiring leaf, and then after immersing the entire leaf in respective hydroponic root medium for at least 1 hour. During this period, turgor pressure was observed to rise and stabilize to a higher value. We assume that this increase in turgor pressure provides a quantitative estimation of the cell wall transpiration tension.

Determination of osmotic pressure of cell wall solutes: The osmotic concentration of the cell wall solutes (π_w) was determined by the differences of the values of turgor pressure (P), cell wall transpiration tension (P_w) and the tissue osmotic pressure (π). For details see Arif (1990).

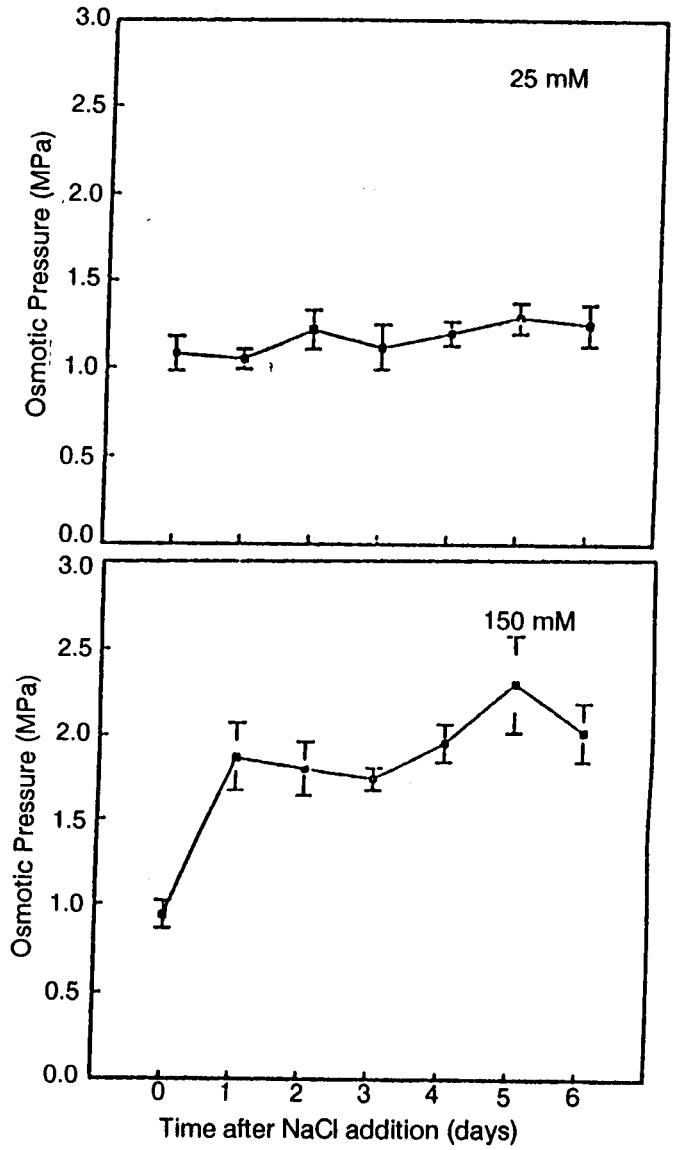

Fig. 1. The response of osmotic pressure of the entire expanding zone of the first emerged leaf to NaCl stress, studied for 6 days.

The estimated cell wall solutes (π_w) for different NaCl treatments after 144 hours of the stress onset are given in Figure 4. It seems that the increase in cell wall solutes corresponds to the amount of external salt stress. π_w was found to be about 0.6 to 0.7 MPa that represents an osmolality equivalent to 145 to 185 mOsm kg^{-1} of water (Fig. 2). This much osmolality can be equivalent to 122 to 142 mol m^{-3} NaCl. These do not include solutes held in Donnan equilibrium of the Donnan free space that will have their

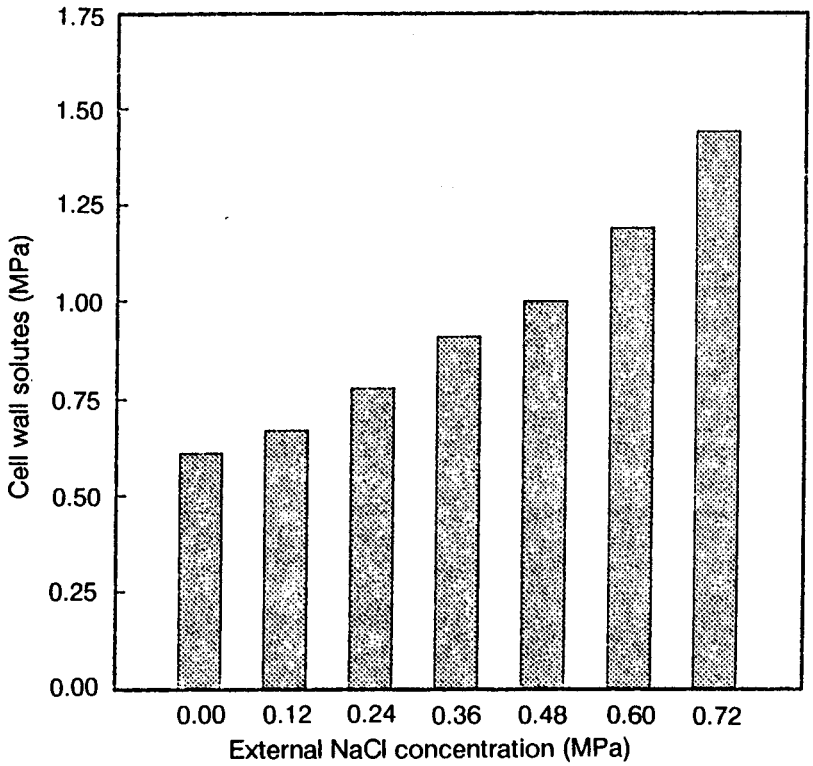

Fig. 2. Estimation of the concentration of osmotically active solutes present in the cell wall of leaf growing zone, indirectly measured after 6 days of the stress application.

effect cancelled out by the Donnan hydrostatic pressure (Tomos, 1988). The presence of so high π_w provides evidence for the possible involvement of the osmotically active cell wall solutes in turgor pressure adjustment. However, the turgor adjustment by this process would not be possible for changes in water potential greater than that. It was, therefore, decided to extend the range of salt stress above the 150 mol m^{-3} in order to test the hypothesis. For the purpose, higher external NaCl concentrations (200 and 250 mol m^{-3}) were applied to the root medium. In sharp contrast to NaCl level up to 150 mol m^{-3}, the turgor pressure declined immediately after the addition of salt in the root medium (Fig. 3). These observations are in consistence with the fact that the cells are taking up all the osmotically active solutes present in the cell walls to maintain their turgor pressure up to the level of 150 mol m^{-3}. Above this level, there was no solutes left behind to maintain the pressure hence the drop was inevitable. This mechanism may have a significant impact on the cell wall osmotic pressure with little effect on that of the cell (Schmalstig and Cosgrove, 1988). Our results are in agreement with their findings, where a similar phenomenon was observed in pea epicotyles in response to stoppage of the solute import into the growing region by removal of the cotyledons. Turgor pressure maintenance was postulated to occur via uptake of solutes from the free space, thereby maintaining the osmotic pressure difference across the plasma membrane. However, in their system about 37% of the solutes were taken into the

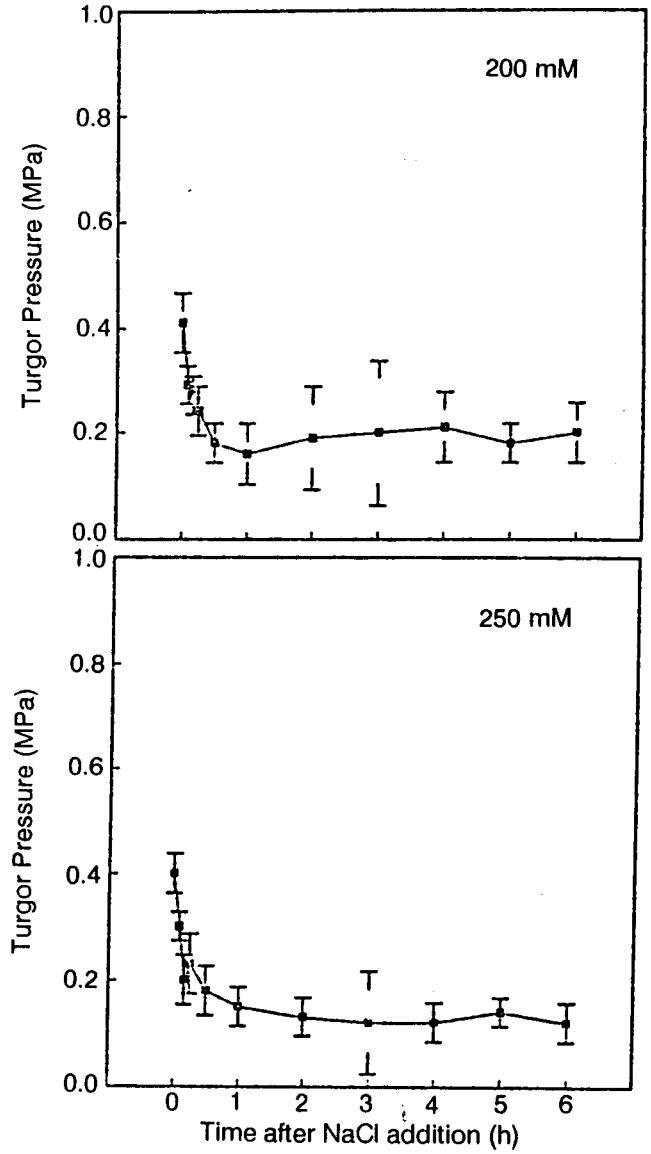

Fig. 3. Behaviour of turgor pressure of leaf expanding cells in response to the NaCl stress studied in a short term experiment i.e. 6 hours (Each point is the mean of 5-12 replicates taken from two experiments).

cell which probably depended upon the extent of the stress applied.

In conclusion, it may be stated that the turgor pressure maintenance was achieved by the active involvement of the solutes present in the cell wall. This mechanism may ultimately contribute towards the maintenance of growth under saline conditions.

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