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**ARTICLE**

# Role of salicylic acid pre-treatment on the photosynthetic performance of tomato plants (*Lycopersicon esculentum* Mill. L. cvar. Rio Fuego) under salt stress

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**ABSTRACT** Imposition of salt stress reduced the net $CO_2$ assimilation rate, chlorophyll (Chl), anthocyanin and carotenoid contents, stomatal conductance and soluble sugar contents of tomato (*Lycopersicon esculentum* Mill. L. cv. Rio Fuego). Pre-treatments of plant with $10^{-4}$ M salicylic acid (SA) could partially restore the $CO_2$ fixation rate and photosynthetic pigment levels under 100 mM NaCl exposure. Accumulation of soluble sugars, a biochemical marker of salinity tolerance in tomato, could be detected in pre-treated plants exposed to high salinity. The improved photosynthetic performance, the accumulation of soluble sugars as compatible osmolytes contributed to the successful acclimation of $10^{-4}$ M SA pre-treated tomato plants to salt stress.

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**KEY WORDS**

pigment content
net $CO_2$ fixation
salicylic acid
salt stress

Salicylic acid (SA), a plant phenolic is now considered as a hormon-like endogenous regulator, and its role in the defence mechanisms against biotic and abiotic stressors has been well documented (Yalpani et al. 1994; Szalai et al. 2000; Horváth et al. 2007). The established effects of SA on stomatal function, chlorophyll content, transpiration rate and respiratory pathways lead to the assumption that SA might possess physiological functions most probably involved in regulation of some photosynthetic reactions. However, short-term treatments with SA (for minutes to 2 hours) did not affect the rate of photosynthesis as compared to the control plants but it was also demonstrated that long-term treatment of barley seedlings with SA decreased the rate of photosynthesis, and increased both $CO_2$ compensation point and stomatal resistance (Pancheva and Popova 1997). High salinity gives rise to ionic and osmotic effects combined with oxidative damage in tissues (Farooq and Azam 2007), thus the synthesis of carbohydrates as organic osmolytes, is an important adaptive response to salt stress. In many species reduction in stomatal conductance due to salt stress may also limit diffusion of $CO_2$ to chloroplasts and consequently net photosynthetic rate (Hajiboland and Hasani, 2007). Furthermore salt stress can decrease the photosynthetic pigment contents, determining a reduction in photosynthetic capacity of plants. The aim of present work was to investigate the effect of SA pre-treatment as a function of time on the photosynthetic performance of tomato (*Lycopersicon esculentum* Mill. L. cv. Rio Fuego) during salt stress.

## Materials and Methods

Tomato plants (*Lycopersicon esculentum* Mill. L. cv. Rio Fuego) were grown in hydroponic cultures in the presence of $10^{-7}$-$10^{-4}$ M salicylic acid (SA). Six-week-old plants were exposed to 100 mM NaCl for a week. Photosynthetic activity measurements were carried out using a portable photosynthesis system (LI-6400, LI-COR, Lincoln, Nebrasca-USA), by an infra red gas analyser (IRGA). The air temperature inside the photosynthesis system cuvette was at 25°C with a vapor pressure deficit (VPD) of 1.2 kPa and relative humidity of 65-70%. After 15 min of dark adaptation the maximum quantum efficiency of PSII primary photochemistry (Fv/Fm) was determined. The leaves were then exposed to actinic light (700 µmol photons $m^{-2}$ $s^{-1}$) to determine the effective quantum yield at PSII ((F'm-Fs)/F'm), photochemical quenching (qP) and non-photochemical quenching (NPQ) in light-adapted samples (Genty et al. 1989). The net photosynthetic rate (A) vs. internal leaf $CO_2$ concentration (A/Ci curves) or vs. increasing photon flux densities (PFDs) were analyzed. The measurements started at 360 µmol $mol^{-1}$ of $CO_2$. Once the steady state was reached, the $CO_2$ concentration was gradually lowered to 50 µmol $mol^{-1}$ and then increased stepwise up to 1200 µmol $mol^{-1}$. The stomatal conductance was determined by digital steady state porometer. Determination of photosynthetic pigment contents were performed by the method of Lichtenthaler (1987). Optical density of the samples was measured by KONTRON Double-Beam spectrophotometer at 470, 534, 643, 661 nm. Total soluble sugar contents were estimated by the method of Dubois et al. (1956).

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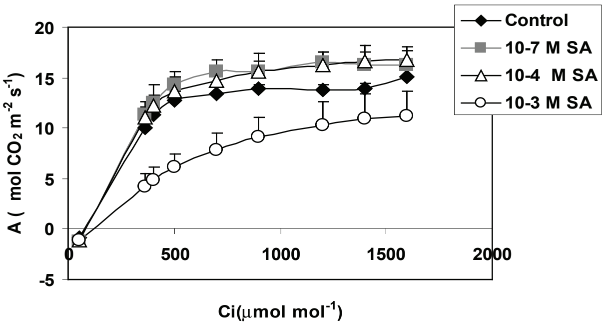

**Figure 1.** Effect of SA pre-treatments on the rate of $CO_2$ fixation as a function of intracellular $CO_2$ concentration in the fully expanded leaves of 7-week-old tomato 24 hours after SA application.

## Results and Discussion

Decreases in stomatal conductivity were observed as a short-term response of pre-treated plants, mainly at $10^{-4}$ M SA concentration. Three-week-long pre-treatment with $10^{-7}$ M, but mainly with $10^{-4}$ M SA, however, increased the stomatal conductance in the presence of 100 mM NaCl compared to the salt stressed control.

After a transient decline short-term pre-treatment with SA did not decrease the chl(*a*+*b*) and carotenoid contents in comparison with control plants. The $10^{-4}$ M SA pre-treatment relieved the salt stress-induced reduction in photosynthetic pigment contents, but this alleviating effect was not so pronounced at $10^{-7}$ M SA concentration.

The decrease in stomatal conductance and photosynthetic pigment contents can reduce the photosynthetic performance under salt stress conditions.

At low light intensities, SA pre-treatment alone did not significantly influence the $CO_2$ assimilation rate, and the maximal quantum yield of primary photochemical reactions at PSII in our system. In plant exposed to high salinity, pre-treatment with $10^{-4}$ M SA ameliorated the net $CO_2$ assimilation rate compared to the salt-stressed control, which could not be observed in case of $10^{-7}$ M SA. Inhibition of net $CO_2$ assimilation (A) by salt stress is one of the effects that high salinity can have on growth and metabolism of plants. The decline in A was correlated with reduction in stomatal conductance in case of salt stress, but not in case of SA pre-treatment. This may indicate that under salt stress stomata were imposing a larger limitation on A, than during SA pre-treatment.

Short-term pre-treatment with $10^{-3}$ M SA decreased the net $CO_2$ assimilation rate as a function of intracellular $CO_2$ concentration (Ci) compared to the control, but the lower concentrations ($10^{-4}$, $10^{-7}$ M SA) were not effective (Fig. 1). Long-term pre-treatment of plants with $10^{-7}$ M and mainly $10^{-4}$ M SA could overcome the decline caused by salt stress in $CO_2$ assimilation rate as a function of $C_i$ one week after the exposure to 100 mM NaCl .

Accumulation of total soluble sugars, a biochemical marker of salinity tolerance of tomato, could be detected in pre-treated plants. Salt stress decreased the total soluble sugar contents in tomato, but the long-term pre-treatment with $10^{-4}$ M SA increased that compared to the salt stressed control.

Long-term application of exogenous SA enhanced the salt stress resistance of plants (Tari et al. 2002). We can conclude that salt tolerance induced by $10^{-4}$ M SA was associated with the activation of the photosynthetic performance and with the accumulation of compatible osmolytes in the roots under salt stress.

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