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Effects of polyamines on the expression of antioxidant genes and proteins in citrus plants exposed to salt stress

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Although there are accumulating reports that polyamines are involved in abiotic/oxidative stress responses, their role is not yet fully understood. Salt stress is one of the most devastating abiotic stresses which seriously interrupt plant growth and productivity. The present study attempts to examine the effects of root treatments with putrescine (Put, 1 mM), spermidine (Spd, 1mM) and spermine (Spm, 1mM) on polyamine homeostasis, as well as on several antioxidant-related genes and proteins in the leaves of citrus plants (*Citrus aurantium* L.) exposed to 150 mM NaCl for 15 d. Analysis of endogenous levels of free polyamines in NaCl-stressed plant tissues reveals the existence of a polyamine transport system from roots to leaves. Real-time analysis of reactive oxygen species (ROS) by confocal laser scanning microscopy (CLSM) showed an over-accumulation of superoxide anion ($O_2^{\bullet-}$) and hydrogen peroxide (H_2O_2) in the stomata of citrus plants exposed to salt stress. Exogenously applied polyamines to salinized nutrient solution induced the activities of superoxide dismutase (SOD), catalase (CAT), glutathione reductase (GR), dehydroascorbate reductase (DHAR) and ascrobic oxidase (AO) whereas it caused the opposite effect on peroxidase (POD), guaiacol peroxidase (GPOD) and ascorbate peroxidase (APX). The effect of polyamines was further examined by determining the plant's antioxidant gene expression profile following a quantitative real-time RT-PCR approach. The overall results indicate that the interaction between different polyamines can be dispersed throughout the citrus plant, and provide additional information suggesting that polyamines may act as a biological mediator allowing citrus plants to activate specific antioxidant responses against salinity.