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ORIGINAL ARTICLE

Overexpression of a cytosolic ascorbate peroxidase from *Panax ginseng* enhanced salt tolerance in *Arabidopsis thaliana*

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Abstract Ascorbate peroxidase (APX) plays an essential role in the antioxidant defense mechanism in the plant, serving in the ascorbate–glutathione cycle for the cellular H_2O_2 metabolism process. As the perennial plant, *Panax ginseng* Meyer encounters a lot of unfavorable growth conditions, and among them soil salinity significantly decreases the yield. Two APX genes from *Panax ginseng* were isolated and designated as *PgAPX1* and *PgAPX2*, which are most similar with previously characterized cytosolic APX of *Daucus carota* and *Spuriopimpinella brachycarpa*, as revealed by sequence analysis of their deduced amino acid sequences. *PgAPXs* transcripts are most abundant in leaf tissue, whereas *PgAPX1* expression level was higher compared to *PgAPX2*. Consistent with higher *PgAPX1* expression during salt stress in ginseng, *PgAPX1*-overexpressing *Arabidopsis* lines ($PgAPX1_{ox}$) increased the germination rate and root length compared with wild-type (WT) under 200 mM NaCl stress treatment. Furthermore, higher chlorophyll content, relative water content, total APX activity, proline content, and lower H_2O_2 accumulation were shown in $PgAPX1_{ox}$ plants compared to WT under 200 mM NaCl stress condition. Transcription analysis showed that $PgAPX1_{ox}$*Arabidopsis* lines were more salt-tolerant by upregulating the ion homeostasis mechanism.

Keywords Oxidative stress · Ascorbate peroxidase · Salt stress · H_2O_2 · *Panax ginseng*

Introduction

Environmental stresses periodically affect plants during their cultivation. These conditions can disrupt the balance of cells metabolism, resulting in elevated reactive oxygen species (ROS) production, for instance, hydrogen peroxide (H_2O_2), hydroxyl radical ($OH^{\cdot}$), singlet oxygen ($^1O_2$) and superoxide ($O_2^{\cdot -}$). Recent study discovered a role of singlet oxygen as initiator of ROS systemic signals (Carmody et al. 2016). At the condition with no stresses, plants produce ROS which act in the oxidative signaling pathway and triggering a lot of cellular functions such as cell apoptosis, stress responses, and developmental processes (Apel and Hirt 2004; Ishikawa et al. 2013; Dietz et al. 2016). However, due to excessive stress exposure, plants can produce higher amount of ROS which induce oxidative damage and reduce plant productivity (Shigeoka et al. 2002).

An efficient antioxidant mechanism in plant integrates antioxidants network and ROS-scavenging enzymes in diverse locations in organelles, cells, and tissues (Ara et al. 2013). Antioxidant enzymes consist of ascorbate peroxidase (APX), superoxide dismutase (SOD), peroxiredoxin (PrxR), glutathione peroxidase (GPX), and catalase (CAT). APX (EC 1.11.1.1) enzymes have an essential function in regulation of ROS levels and H_2O_2 scavenging networks from cytosol and chloroplast of plant cells. APX detoxify H_2O_2 utilizing ascorbate (AsA) as a substrate. Through

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