Journal of Plant Physiology **164** (2007) 1469—1479

Available online at www.sciencedirect.com

ScienceDirect

JOURNAL OF PLANT PHYSIOLOGY

www.elsevier.de/jplph

# The participation of hydrogen peroxide in methyl jasmonate-induced $NH_4^+$ accumulation in rice leaves

**Kuo Tung Hung, Ching Huei Kao***

*Department of Agronomy, National Taiwan University, Taipei, Taiwan, Republic of China*

Received 22 August 2006; received in revised form 14 October 2006; accepted 17 October 2006

**KEYWORDS**
$H_2O_2$;
Methyl jasmonate;
$NH_4^+$;
*Oryza sativa*

## Summary

Ammonium is a central intermediate in the nitrogen metabolism of plants. We have previously shown that methyl jasmonate (MJ) not only increases the content of $H_2O_2$, but also causes $NH_4^+$ accumulation in rice leaves. More recently, $H_2O_2$ is thought to constitute a general signal molecule participating in the recognition of and the response to stress factors. In this study, we examined the role of $H_2O_2$ as a link between MJ and subsequent $NH_4^+$ accumulation in detached rice leaves. MJ treatment resulted in an accumulation of $NH_4^+$ in detached rice leaves, which was preceded by a decrease in the activity of glutamine synthetase (GS) and an increase in the specific activities of protease and phenylalanine ammonia-lyase (PAL). GS, PAL, and protease appear to be the enzymes responsible for the accumulation of $NH_4^+$ in MJ-treated detached rice leaves. Dimethylthiourea (DMTU), a chemical trap for $H_2O_2$, was observed to be effective in inhibiting MJ-induced $NH_4^+$ accumulation in detached rice leaves. Scavengers of free radicals (sodium benzoate, SB, and glutathione, GSH), nitric oxide donor (*N-tert*-butyl-$\alpha$-phenylnitrone, PBN), the inhibitors of NADPH oxidase (diphenyleneiodonium chloride, DPI, and imidazole, IMD), and inhibitors of phosphatidylinositol 3-kinase (wortmannin, WM, and LY 294002, LY), which have previously been shown to prevent MJ-induced $H_2O_2$ production in detached rice leaves, inhibited MJ-induced $NH_4^+$ accumulation. Similarly, changes in enzymes responsible for $NH_4^+$ accumulation induced by MJ were observed to be inhibited by DMTU, SB, GSH, PBN DPI, IMD, WM, or LY. Seedlings of rice cultivar Taichung Native 1 (TN1) are jasmonic acid (JA)-sensitive and those of cultivar Tainung 67 (TNG67) are JA-insensitive. On treatment with JA, $H_2O_2$ accumulated in the leaves of TN1 seedlings but not in the leaves of TNG67. Ethylene action inhibitor, silver thiosulfate, was observed to inhibit MJ- and abscisic

*Abbreviations:* ABA, abscisic acid; DMTU, dimethylthiourea; DPI, diphenyleneiodonium chloride; FW, initial fresh weight; GS, glutamine synthetase; IMD, imidazole; JA, jasmonic acid; LY, LY 294002; MJ, methyl jasmonate; PAL, phenylalanine ammonia-lyase; PI3K, phosphatidylinositol 3-kinase; PI3P, phosphatidylinositol 3-phosphate; ROS, reactive oxygen species; STS, silver thiosulfate; TN1, Taichung Native 1; TNG67, Tainung 67; WM, wortmannin

*Corresponding author. Fax: +886 2 23620879.
*E-mail address:* kaoch@ntu.edu.tw (C.H. Kao).

0176-1617/$ - see front matter © 2006 Elsevier GmbH. All rights reserved.
doi:10.1016/j.jplph.2006.10.005

acid-induced accumulation of $NH_4^+$ and changes in enzymes responsible for $NH_4^+$ accumulation in detached rice leaves, suggesting that the action of MJ and ABA is ethylene dependent.
© 2006 Elsevier GmbH. All rights reserved.

## Introduction

Ammonium is a central intermediate in the nitrogen metabolism of plants. Glutamine synthetase (GS) is a key enzyme in $NH_4^+$ assimilation and catalyzes the ATP-dependent condensation of $NH_4^+$ with glutamate to produce glutamine (Miflin and Lea, 1976). Phenylalanine ammonia-lyase (PAL) catalyzes the elimination of $NH_4^+$ from phenylalanine producing *trans*-cinnamic acid (Hahlbrock and Grisebach, 1979). $NH_4^+$, released from the PAL reaction, is known to be incorporated into glutamine by the action of GS (Razel et al., 1996; van Heerden et al., 1996). Sakurai et al. (2001) provided evidence to show that GS is partly coupled to the reaction of PAL in developing rice leaves. Cd-induced $NH_4^+$ accumulation in rice leaves is associated with decreases in GS activity and increases in PAL specific activity (Hsu and Kao, 2004).

GS activity in plants is known to be regulated at the levels of transcription and turnover. Oxidative modification of GS has been implicated as the first step in the turnover of GS in bacteria (Levine, 1983; Rivett and Levine, 1990). Stieger and Feller (1997) have shown that GS degradation in illuminated chloroplasts requires the photosynthetic electron transport chain. Chloroplastic GS of wheat seedlings has been reported to be particularly prone to degradation under oxidative stress conditions (Palatnik et al., 1999). By incubating soybean root extracts enriched in GS in a metal-catalyzed oxidation system to produce the hydroxyl radical, Ortega et al. (1999) have shown that GS is oxidized and that the oxidized GS is inactive and more susceptible to proteolysis than nonoxidized GS. It is clear that GS degradation requires the participation of reactive oxygen species (ROS). We also demonstrated that paraquat, which is known to produce ROS, decreased GS activity and increased $NH_4^+$ content in rice leaves in the light (Chien et al., 2002). It has been shown that protease specific activity (or proteolysis) increased under photooxidative environmental conditions and treatment with a hydroxyl radical generating system or $H_2O_2$ (Casano and Trippi, 1992; Casano et al., 1990, 1994). Kumar and Knowles (2003) demonstrated that PAL specific activity induced by wounding in potato tubers is related to the ability to produce superoxide radicals.

Recently, researchers have focused on the functional aspects of $H_2O_2$. $H_2O_2$ is a constituent of oxidative metabolism and is itself a ROS. Because $H_2O_2$ is a small, diffusible, and ubiquitous molecule that can be synthesized, as a stimulus, it fulfills the important criteria for an intracellular messenger (Neill et al., 2002; Foyer and Noctor, 2005). Thermoprotection obtained by spraying salicylic acid or by heat acclimation was suggested to be achieved by a common signal transduction pathway involving very early increases in $H_2O_2$ content (Dat et al., 1998). In tomato plants, $H_2O_2$ has been shown to act as a second messenger for induction of defense genes in response to wounding and systemin (Orozco-Cárdenas et al., 2001). It has been demonstrated that $H_2O_2$ is required for the induction of cytosolic ascorbate peroxidase mRNA by oxidative stress (Morita et al., 1999). $H_2O_2$ has now also been shown to be a critical component of abscisic acid (ABA)-induced stomatal closure (Pei et al., 2000; Zhang et al., 2001; Kwak et al., 2003) and ABA-induced rice leaf senescence (Hung and Kao, 2004b), ABA-induced activities of ascorbate peroxidase and glutathione reductase in rice roots (Tsai and Kao, 2004), and gibberellic acid-induced programed cell death in barley aleurone cells (Fath et al., 2001).

Methyl jasmonate (MJ) was first considered to be secondary metabolite with a possible application in the perfume industry (Demole et al., 1962). It is now evident that jasmonates are a class of plant hormones, which mediate various aspects of developmental and stress responses (Creelman and Mullet, 1997). MJ has been shown to cause $H_2O_2$ production in parsley suspension-cultured cells (Kauss et al., 1994) and to act as a signal molecule for the induction of defense genes in tomato plants (Orozco-Cárdenas et al., 2001). We have previously shown that MJ not only increases the content of $H_2O_2$ (Hung and Kao, 2004a), but also causes $NH_4^+$ accumulation (Chen and Kao, 1998) in rice leaves. In this paper, we have examined the possible involvement of $H_2O_2$ in MJ-induced $NH_4^+$ accumulation in rice leaves.

### Materials and methods

#### Plant materials and treatments

Rice (*Oryza sativa* L., cv. Taichung Native 1, TN1, or Tainung 67, TNG 67) seeds were sterilized with 2.5%

Download English Version:

https://daneshyari.com/en/article/2057673

Download Persian Version:

https://daneshyari.com/article/2057673

Daneshyari.com