Possible Influence of Organic Acids on Zn Homeostasis in Roots of *Malus hupehensis* (Pamp.) Rehd under Zn Deficiency and Zn Toxicity

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INTRODUCTION

Zinc (Zn) is an essential micronutrient for various physiological and metabolic processes in plants. To maintain a balance of Zn between excess and deficiency, plants have developed various homeostasis mechanisms, among which organic acids are considered important (Haydon et al., 2007; Mathys, 1977, Sarret et al., 2002). Apple is the most commonly consumed fruit in the world. However, without proper Zn nutrition, both apple yield and nutritional quality can be limited. Thus, study of the role of organic acids in apple Zn homeostasis is not only helpful to reveal the possible resistance mechanisms, but also critical for apple production.

METHODS

Pre-cultured 14-day *Malus hupehensis* (Pamp.) Rehd seedlings were grown in solutions with three different Zn concentrations: Zn deficiency (-Zn, Zn activity was pZn^{2+} 11.3), adequate Zn (Control, Zn, Zn activity was pZn^{2+} 10.7) and Zn toxicity (+Zn, Zn activity was pZn^{2+} 8.3) for 1d, 5d, 13d, and 20d, respectively.

In a separate experiment for making sure the correlations between Zn and orgnic acid concentrations, pre-cultured 14-day *M. hupehensis* (Pamp.) Rehd seedlings were grown in a basal nutrient solution with low Zn concentrations (0, 0.5, 1, 1.5, 2 μM Zn^{2+}) and high Zn concentrations (40, 60, 80, 100 μM Zn^{2+}) for 1 d.

Organic Zn and organic acid concentrations were determined by AAS and HPLC.

RESULTS AND DISCUSSION

Compared with the control, the concentrations of malic acid in roots of *M. hupehensis* (Pamp.) Rehd increased 1.4 and 1.5 fold under Zn deficiency and Zn toxicity (1 d exposure), respectively (Fig. 1.). Meanwhile, Zn concentrations in roots varied most (Fig. 2.), indicating that the root is the most sensitive organ to feel initial Zn stress. Significant correlations among root total Zn and solution Zn concentrations and oxalic acid and malic acid concentrations in the roots of *M. hupehensis* (Pamp.) Rehd were observed (Table 1). As organic acids could together with Zn move from one cell to another, organic acids may be important Zn ligands involved in Zn homeostasis (Haydon et al., 2007; Mathys, 1977).

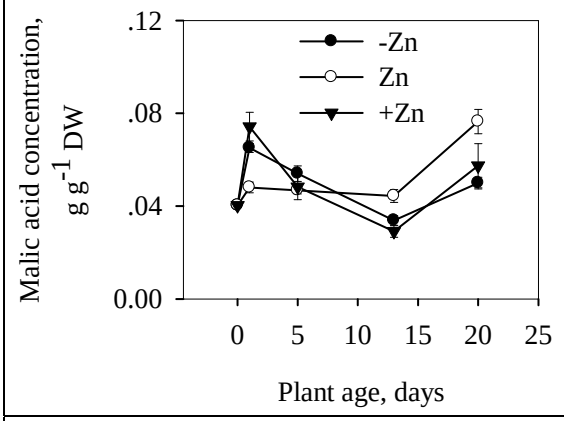

Fig. 1. Changes in concentration of malic acid in the roots under Zn stress in *M. hupehensis* (Pamp.) Rehd

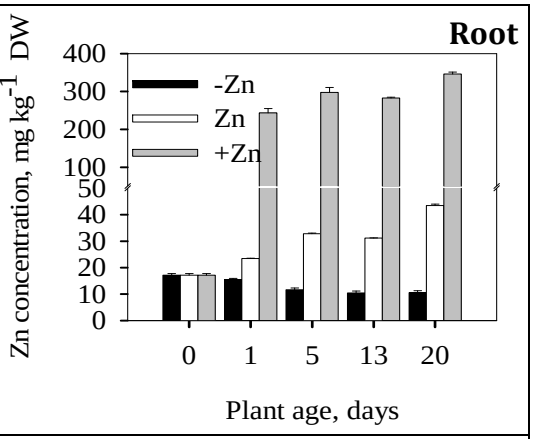

Fig. 2. Changes of Zn concentration in the root, stem and leaf under Zn stress in *M. hupehensis* (Pamp.) Rehd

Table 1. Correlations between organic acids and Zn concentrations in solution and root of *M. hupehensis* (Pamp.) Rehd under low and high Zn concentrations (1 d exposure)

N=12/15	Root (low Zn level)		Root (high Zn level)	
	Oxalic acid	Malic acid	Oxalic acid	Malic acid
Solution Zn concentrations	-0.660**	-0.877**	0.708**	0.695*
Root Zn concentrations	-0.772**	-0.951**	0.930**	0.970**

CONCLUSIONS

The results indicate that the increase in concentrations of root organic acids is important for the resistance to Zn deficiency and toxicity in *M. hupehensis* (Pamp.) Rehd.

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