

Change of Mineral Elements and Amino Acids in *Malus hupehensis* var. *pingyiensis* Leaves under Cd Treatment

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Abstract

The objective of this paper is to research the effects of CdCl₂ treatment on mineral elements and amino acids in leaves of *Malus hupehensis* var. *pingyiensis*. The seedlings of *Malus hupehensis* var. *pingyiensis* with 6 leaf were cultured in 1/2 Hoagland nutrient solutions of different CdCl₂ treatments (0, 0.5, 5 and 10 mg·L⁻¹), respectively. The mineral elements and amino acids of the leaves in *Malus hupehensis* var. *pingyiensis* were measured in the day 30. Compared with the control (0 mg·L⁻¹ CdCl₂), the treatments significantly decreased the contents of Mg, Fe and Zn in the tested leaves and obviously increased the contents of Cd in the experimental leaves. As to Ca and Mn, low concentration Cd treatment (0.5 mg·L⁻¹ CdCl₂) promoted their absorption, however, high concentration Cd treatments (5 and 10 mg·L⁻¹ CdCl₂) inhibited their absorption. The metabolism pathway and content of amino acids in the *Malus hupehensis* var. *pingyiensis* leaves under Cd treatment were modified, the content of amino acids in the glycolate pathway became larger than that in control, the content of amino acids in the pyruvic acid synthesis pathway and tyrosine and phenylalanine became smaller than that in control, the content of other amino acids also had made a certain degree change. The results provided the important basis for safety production and quality evaluation of leaves in *Malus hupehensis* var. *pingyiensis*.

Keywords

Malus hupehensis var. *pingyiensis*, CdCl₂ Treatment, Mineral Elements, Amino Acids

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1. Introduction

The content of Cd released by people in the world in the near 50 years reached about 22,000 t [1], a large number of Cd got into soils, and caused the heavy metal pollution of farmland, which became an important source of heavy metal farmland pollution. The photosynthesis, DNA damage, fatty acid composition and lipid peroxidation of plant had been explored by some researchers [2] [3] [4]. *Malus hupehensis* var. *pingyiensis* is a kind of peculiarly woody plant in China, belonging to tea plant. Quality is a vital indicator of tea traits in the process of production. Mineral elements such as Ca, Mg, Fe, Mn, Zn were important macroelement and microelement needed by human body, the amino acid was one of macromolecules with multitudinous biological activity of biological organism, both of them should go hand in hand with quality of tea. Moreover, the quality of tea was also affected by age, processing technology, application of nitrogen fertilizer, growth environment and other factors of tea plant [5] [6]. Quality of tea was effectively improved with the use of organic fertilizer [7]. What happened to the mineral elements and amino acid of leaves in *Malus hupehensis* var. *pingyiensis* under Cd treatment? The problem studied would help to explain their mechanisms influenced by Cd stress. In this article, change of mineral elements and amino acids in *Malus hupehensis* var. *pingyiensis* leaves under Cd treatment were studied, the results will provide the important basis for safety production and quality evaluation of leaves in *Malus hupehensis* var. *pingyiensis*.

2. Materials and Methods

2.1. Materials and Treatments

According to the test method [8], firstly, the concentrated CdCl₂ solution was mixed with the one-half Hoagland's solutions to make the solutions with CdCl₂ mg·L⁻¹ of 0, 0.5, 5, 10, respectively. Secondly, the seedlings of *Malus hupehensis* var. *pingyiensis* with 6 leaf were planted into and cultivated in the above solutions. The seedlings were measured for 30 days after CdCl₂ treatment, repeated for three times.

2.2. Measurement of Mineral Elements

According to the test method [9], the content of mineral elements including Ca, Mg, Fe, Zn, Mn and Cd in the leaves of *Malus hupehensis* var. *pingyiensis* was determined by TAS-990 atomic absorption spectrophotometer.

2.3. Measurement of Amino Acids

The content of amino acids including aspartic acid, threonine, serine, glutamic acid, proline, glycine, alanine, cysteine, valine, methionine, isoleucine, leucine, tyrosine, phenylalanine, histidine, lysine and arginine in the *Malus hupehensis* var. *pingyiensis* leaves was measured according to the test method [10].

2.4. Data Analysis

The data in the article were completed with Excel statistical software 2003 and SPSS 17.0 statistical software package, the significant difference was conducted by Duncan's new multiple range method.

3. Results and Analysis

3.1. Variation Characteristics of Mineral Elements

The effects of CdCl₂ treatment on the absorption of different mineral elements had a certain degree of difference. As far as Ca and Mn were concerned, 0.5 mg·L⁻¹ CdCl₂ treatment promoted the absorption of the two kinds of elements, however, their absorption was restrained by CdCl₂ treatments with the increase Cd concentration. For comparison with Mn, the inhibition degree of Ca affected by Cd treatment was larger. Moreover, the content of Cd in the leaves in different Cd treatments became significantly increase than that in control (0 mg·L⁻¹ CdCl₂ treatment), the content of Mg, Fe and Zn in the leaves was obvious smaller than that in the control with the increase Cd concentration (**Table 1**).

3.2. Changes of Amino Acids

It was shown in the **Table 2** that CdCl₂ treatment reduced the contents of arginine and aspartic acid in the leaves. The effects on content of tyrosine and phenylalanine in the pentose-phosphate pathway in the leaves by CdCl₂ treatment were relative smaller among all amino acids. The effects on content of glycine and serine of the glycolate pathway under CdCl₂ treatment was larger and became increase. CdCl₂ treatment promoted synthesis of alanine, valine and leucine in the pyruvic acid synthesis pathway. However, the amino acids in the serine synthesis pathway in the leaves had no similar trend of change, the content of serine and glycine became bigger in all the CdCl₂ treatments than that in control (0 mg·L⁻¹ CdCl₂ treatment), the content of cysteine in the leaves was smaller in the lower CdCl₂ concentration treatment (0.5, 5 mg·L⁻¹ CdCl₂), its content in the leaves was larger under 10 mg·L⁻¹ CdCl₂ treatment compared to the control.

Table 1. Effects on some mineral elements for *Malus hupehensis* var. *pingyiensis* leaves under CdCl₂ treatment.

Treatment concentration (mg·L ⁻¹)	Ca (mg·kg ⁻¹)	Mg (mg·kg ⁻¹)	Fe (mg·kg ⁻¹)	Zn (mg·kg ⁻¹)	Mn (mg·kg ⁻¹)	Cd (mg·kg ⁻¹)
0	8342 ± 278b	2790 ± 72a	122 ± 4a	24.8 ± 0.6a	28.1 ± 1.9b	1.4 ± 0.2d
0.5	8735 ± 106a	1983 ± 58b	118 ± 3a	21.9 ± 1.1b	30.0 ± 3.3a	2.6 ± 0.3c
5	7825 ± 166c	1743 ± 67c	104 ± 3b	17.8 ± 0.6c	26.2 ± 1.3c	13.7 ± 0.3b
10	6981 ± 94d	1557 ± 31d	95 ± 3c	11.4 ± 0.4d	26.7 ± 2.1c	15.8 ± 0.4a

Duncan's multiple test, different letter in the brackets indicated the significant differences among the different treatments in the same time, small letter stand for 5% level.

Table 2. Effects on amino acids for *Malus hupehensis* var. *pingyiensis* leaves under CdCl₂ treatment.

Type of amino acids	Content of amino acids			
	0 mg·L ⁻¹ CdCl ₂ treatment	0.5 mg·L ⁻¹ CdCl ₂ treatment	5 mg·L ⁻¹ CdCl ₂ treatment	10 mg·L ⁻¹ CdCl ₂ treatment
aspartic acid	1.70	1.38	1.01	0.97
threonine	0.28	0.30	0.31	0.33
serine	0.29	0.31	0.35	0.33
glutamic acid	0.76	1.06	1.17	1.30
proline	0.39	0.63	0.25	0.78
glycine	0.26	0.31	0.34	0.33
alanine	0.29	0.33	0.36	0.34
cysteine	1.48	1.34	1.43	1.99
valine	0.87	0.85	0.80	1.05
methionine	1.34	1.07	1.20	1.57
isoleuci	0.72	0.70	0.71	0.88
leucine	0.81	0.85	0.88	1.09
tyrosine	0.26	0.24	0.27	0.27
phenylalanine	0.21	0.20	0.23	0.21
histidine	0.37	0.16	0.14	0.41
lysine	0.52	0.38	0.31	0.52
arginine	0.59	0.51	0.37	0.45
essential amino acids	4.75	4.35	4.44	5.65
non-essential amino acids	6.39	6.27	5.69	7.17
Total amino acids	11.14	10.62	10.13	12.82

Low Cd concentration treatment reduced the content of the essential amino acids and non-essential amino acids in human body by 4.67%, 9.07%, respectively. However, high Cd concentration treatment (10 mg·L⁻¹ CdCl₂) raised the content of the total amino acids in *Malus hupehensis* var. *pingyiensis* leaves. In all, the effects of Cd treatment on amino acids metabolism pathway had obvious variation.

4. Discussion

4.1. Mineral Elements

Mineral elements in plant are the important component of plant leaf, which affect the production capacity and quality of plant. The content of mineral elements in plant leaf was influenced by soil type, soil water, heavy metal content,

plant varieties and so on. Seasonal variations of leaf element content had existed in plant [11]. Mineral elements content and change in *Macadamia ternifolia* leaves in the development period were researched, its results showed that the contents of 7 kind of mineral elements indicated regular change in the leaves of three *Macadamia ternifolia* varieties [12]. 7 kinds of mineral elements (including Cu, Zn, Pb, Ni, Mn, K, P) are confirmed the characteristics elements of *Lagera pterodonta* [13]. The relationship between contents of mineral elements and fruit quality indexes were studied, the results indicated that controlling or reducing N application, with adding P, K, Zn and Mn appropriately improved its fruit quality [14].

Cd is one kind of important pollution sources for soil, it affected growth, quality, element absorption and distribution of plants. In the paper, the lower concentration CdCl₂ treatment (0.5 mg·L⁻¹) promoted the absorption of Ca and Mn in the *Malus hupehensis* var. *pingyiensis* leaves, the results were not consisted with the report [15] [16], the reason should be further researched in the following years. However, the treatment inhibited the absorption of Mg, Fe, Zn in the *Malus hupehensis* var. *pingyiensis* leaves. In the higher concentration Cd treatment (5 mg·L⁻¹, 10 mg·L⁻¹), the contents of five elements including Ca, Mn, Mg, Fe, Zn in the leaves declined, but the content of Cd in the leaves raised, the conclusion was not completely in line with the studied result [15] [16], the researched reports showed that the mechanism of plant absorption elements such as Ca, Mn, Mg, Fe, Zn was different. Those results resulted in decrease of leaves quality in *Malus hupehensis* var. *pingyiensis*. Because of the increase of Cd and the decrease of some mineral elements such as Mn, Fe and Zn absorption in the leaves with the increase of Cd concentration treatment, the quality of the tested leaves declined, these Cd-polluted leaves drunk by people would impact the health of human. Breeding of Cd-tolerant plant variety is becoming an important problem to be resolved, it directly influences product safety of plant and human healthy. In the following years, the research on selection of Cd-tolerant plant variety by using many methods and technologies should be accelerated, it will help to normally grow for plant and ensure safety of product quality.

4.2. Amino Acids

Content and types of Amino acids in plant tissues determined plant product quality. Amino acids content was affected by plant population, varieties, weather condition, soil type, heavy metal and other factors [17] [18]. Organic fertilizer increased the free amino acids content and quality in tea leaves [7]. Relational cultivation technologies raised the essential amino acids content in winter wheat [10]. Cd treatment reduced the serine and isoleucine contents and made free amino acids content no significant change in rat [19]. In the paper, different Cd concentration treatment promoted the serine contents, the result was different from the Gu *et al.*'s conclusion, low Cd concentration treatment (0.5 mg·L⁻¹, 5 mg·L⁻¹) also declined isoleucine contents that was coincided with the Gu *et al.*'s

result [19], and reduced the content of the essential amino acids, non-essential amino acids and total amino acids, however, high Cd concentration treatment ($10 \text{ mg}\cdot\text{L}^{-1}$) increased the contents of isoleucine, essential amino acids, non-essential amino acids and total amino acids (Table 2). Cd treatments varied the amino acids metabolism pathway, the contents of all the other amino acids had different change. Amino acids are the raw materials of protein synthesis and products of protein decomposition. The reason why content of some amino acids became bigger compared to control might be that the elevation of cell membrane permeability and related protein degradation, and the decrease in content of other amino acids compared to control might be resulted from the inhibition of those matters transport and related protein degradation, the mechanism on amino acids metabolism influenced by Cd treatment should be explored through further scientific experiments.

5. Conclusions

1) The contents of mineral elements in the experimental leaves with different Cd treatments significantly varied. The effects of different Cd treatments on absorption of Ca and Mn were different. $0.5 \text{ mg}\cdot\text{L}^{-1}$ CdCl_2 treatment promoted the absorption of Ca and Mn, higher concentration Cd treatment ($5 \text{ mg}\cdot\text{L}^{-1}$, $10 \text{ mg}\cdot\text{L}^{-1}$) decreased the absorption of Ca and Mn in the *Malus hupehensis* var. *pingyiensis* leaves. All the Cd treatments reduced the contents of Mg, Fe, Zn and Cd in the tested leaves.

2) Lower Cd concentration treatment reduced the content of the essential amino acids and non-essential amino acids in human body, by 4.67%, 9.07%, respectively. Higher Cd concentration treatment ($10 \text{ mg}\cdot\text{L}^{-1}$ CdCl_2) raised the content of the total amino acids in *Malus hupehensis* var. *pingyiensis* leaves. The effects of Cd treatment on amino acids metabolism pathway had obvious difference.

Support Information

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