Europ.J.Hort.Sci., **76** (2). S. 69–74, 2011, ISSN 1611-4426. © Verlag Eugen Ulmer KG, Stuttgart

# Cinnamaldehyde Prolongs the Vase Life of Cut Rose through Alleviating Oxidative Stress

H. Jing, X. Tan, J. Xu, G. Zhou and G. Li
(Henan University of Technology, College of Biological Engineering, Zhengzhou, China)

**Summary**

Cinnamaldehyde (CA) is a major component of volatile oil extracted from the leaves and bark of *Cinnamomum osmophloeum* Kaneh. In the present study, effects of CA were investigated on the vase life of cut rose. Our results showed that CA markedly enhanced the vase life of rose by 2.8 more days in comparison to control. This increase in vase life is chiefly governed by CA induced higher activities of antioxidant enzymes POD, SOD and CAT that in turn lowered the levels of MDA. Besides that proline and soluble protein contents were also improved. Therefore, CA could be used in commercial preservatives to improve the longevity of cut rose.

**Key words.** Cinnamaldehyde – rose – cut flower – refreshing – reactive oxygen species

## Introduction

Reactive oxygen species (ROS) is produced in higher plant in many metabolic processes, even under optimal conditions. The sites of ROS production in plants cell are the organelles of chloroplasts, mitochondria and microbodies with highly oxidazing activities or with sustained electron flows (Edreva 2005). For example the electron transport chain overloaded and the active chlorophyll absorption light energy in chloroplast were both attributed to the ROS production in photosynthetic plants (Sara et al. 2008). Besides the organelles of plant, Sara et al. (2008) also reported that other main sources of ROS were peroxidases and oxidases, such as NADPH oxidase, NADH oxidase, xanthine oxidase, etc. in plants.

Many researches have clearly showed that lots of ROS, such as hydrogen peroxide ($H_2O_2$), superoxide radical ($O_2^{\cdot-}$), and hydroxyl radical ($OH^{\cdot-}$), will deoxidize nearby structures including DNA, proteins or lipids (Barja 2004; Yin and Chen 2005) which can be damaging or even fatal for the cell (Mittler 2002). Kumar et al. (2007) reported that a burst of $O_2^{\cdot-}$ generation was accompanied during the senescence of rose petals. Rose petals were more sensitive to ROS because of antioxidant defence capacity limited at the later period of maturation (Kumar and Srivastava 2008).

Oxidative damage of lipids will be formed toxic products of malondialdehyde (MDA) by ROS accumulation. Therefore, MDA is usually as an index of the degree of plant oxidative stress (Hodges et al. 1999). In order to sustain relative stable circumstance in plant cells, plant cells generally possess enzymic and non-enzymic mechanisms which can protect them against oxidative damage to their components. Reduced glutathione (GSH) and reduced ascorbic acid (ASA), as non-enzymic molecules, protect the cell of cut rose from ROS damage. In senescing rose petals, decline of GSH and ASA leads to shift the cellular redox toward more oxidized state (Kumar and Srivastava 2008; Kumar et al. 2008). In the enzymic scavenging of ROS, Superoxide dismutases (SODs) catalyse the dismutation of $O_2^{\cdot-}$ to $H_2O_2$ and $O_2$. Removal of $H_2O_2$ was catalyzed by a variety of peroxidases (PODs) and catalases (CATs) (Rinalducci et al. 2008). CAT dismutates $H_2O_2$ into water and molecular oxygen whereas POD decomposes $H_2O_2$ by oxidation of co-substrates such as phenolic compounds and/or antioxidants (Meloni et al. 2003). Accordingly, SOD, POD and CAT have important functions in scavenging ROS.

Cinnamaldehyde (CA), a major bioactive compound isolated from the leaves and bark of *Cinnamomum osmophloeum* Kaneh (Cheng et al. 2006), was used in variety of domains, such as antioxidant (Singh et al. 2007), antimicrobial (Matan et al. 2006), antipyretic (Kurokawa et al. 1998), anti-inflammatory (Kim et al. 2007) and antidiabetic (Andrerson et al. 2004). However, relatively little is known about the effects of CA on the vase life of cut rose and the enzymic scavenging system of ROS. Therefore, In the paper, the results concerning the relationship between CA and ROS enzymatic scavenging system and ROS damage production were reported in the cut rose cv. 'Pink Queen'.

## Material and Methods

### *Plant materials, treatments, and environmental conditions*

Cut rose (*Rosa hybrida* L.) cv. 'Pink Queen' flowers were obtained from a local flowering plants market in Zhengzhou, Henan, China. The fresh vivid flowers were picked up and immediately placed in tap water, then delivered to the laboratory within 2 h. After declinately recutting the stems to a length of 30 cm under water, the flowers were treated with distilled water as control, 0.1 % or 0.3 % of CA as experimental group in 500 mL Erlenmeyer flask

contained about 250 mL treated solutions, respectively. The flowers were then placed in a climate-controlled room at 20–25 °C, 30–40 % relative humidity (RH), and 140 μmol $m^{-2}$ $s^{-1}$ light intensity (LI) to simulate commercial vase life. The experiment was repeated three times.

### *Morphological observations*

Vase life was measured by the period from the first vase day to the end of vase life when the flowers lost ornamental value, as defined by pedicel bending, flower petal wilting and bluing, and general discoloration (Pompodakis and Joyce 2003). A flower opening index was determined as follows: Stage 0, unopened bud; Stage 1, partially opened bud; Stage 2, completely opened bud; Stage 3, partially opened flower; Stage 4, fully opened flower without anther appearance; and Stage 5, fully opened flower with anther appearance (yellow) (Wang et al. 2004).

### *Fresh weight and water balance measurements*

Fresh weight and water balance were both measured by electronic balance. Total weight (Erlenmeyer flask, flowers and solutions) and flowers weight were taken every day. The changes in fresh weight were presented as the percentage of initial weight. Otherwise, Loss and absorption of water was the difference of total weight and total weight besides flower in two continuous day, respectively. Water balance was water absorption minus loss water.

### *Assays of SOD, POD, CAT activity*

The total activity of SOD was assayed according to Dhindsa and Thorpe (1981), with some modifications. 1 g of petals was ground with liquid nitrogen. For SOD, the enzyme was extracted with 5 mL 50mM of phosphate buffer (pH 7.8) containing 1 mM EDTA and 50 mg polyvinylpyrolidone (PVP-10). Extracts were filtered through two layers of cheesecloth and centrifuged at 12,000 g for 15 min. SOD activity was determined spectrophotometrically at 560 nm with reduction of nitroblue tetrazolium (NBT). One unit of SOD activity was defined as the amount of sample to reach an inhibition of 50 % of the NBT reduction rate.

Extracts used to assay CAT activity is same as the SOD activity. CAT activity was determined spectrophotometrically at 405 nm with 5 % ammonium molybdate for 10 min. A calibration curve was established by means of different concentration $H_2O_2$.

POD activity was measured by use of guaiacol (Maehly et al. 1954). 0.5 g of petals was ground with liquid nitrogen. For POD, the enzyme was extracted with 5 mL of 0.1 M Tris-HCL buffer (pH 8.5) and centrifuged at  g for 15 min. POD activity was measured spectrophotometrically at 470 nm and recorded the value of change in 5 min after admixing of 0.8 mL extracts and the reaction solution. Reaction solution contained 50 mL 0.2 M phosphate buffer (pH 6.0), 28 μL $H_2O_2$ and 19 μL guaiacol. One unit of POD activity was defined as the amount of sample to change 0.01 $min^{-1}$.

### *Measurements of $O_2^{\cdot-}$, $H_2O_2$, proline, soluble protein and MDA content*

$O_2^{\cdot-}$ content was determined according to the method developed by Elstner and Heupel (Oracz et al. 2007). The supernatants used for $O_2^{\cdot-}$ determination was isolated by the same way as the SOD activity assayed. The supernatant (1 ml) was first incubated at 25 °C for 30 min in presence of 1 mM hydroxylamine hydrochloride in 50 mM sodium phosphate buffer (pH 7.8). Then, 2 ml of this reaction mixture was incubated with 0.5 ml of 17 mM sulfanilamide and 0.5 ml of 7 mM 2-naphtylamine at 25 °C for 30 min. The absorbance was measured at 530 nm after centrifugation at 13,000 g for 10 min. A calibration curve was established using sodium nitrite. The results are expressed as μg $g^{-1}$ FW.

To measure $H_2O_2$ content, rose petals (0.2 g FW) were ground in 1.4 ml of cold 5 % trichloroacetic acid (TCA) (Patterson et al. 1984). The extracts were centrifuged at 12,000 g for 15 min, the supernatants were used to detect $H_2O_2$ content using hydrogen peroxide colorimetric detection kits according to the instructions of manufacturer. (Nanjing Jiancheng Company of biological technology, China) (Zhang 2009).

To determine the proline content, 0.2 g of rose petals was ground in 5 ml of 3 % salicylsulfonic acid (Aspinal and Paleg 1981). The extracts were boiled for 10 min and then centrifuged at 12, 000 g for 15 min. Then 2 ml of supernatants was added 2 ml water and glacial acetic acid and 4 ml of 2.5 % ninhydrin. The mixtures were boiled or 60 min and extracted by 4 ml of methyl benzene. The phase of methyl benzene was tested spectrophotometrically at 520 nm. The results were calculated based on the calibration curve.

To assay of soluble protein content, the supernatant was extracted by the same way as the POD activity. 0.1 ml of the extracts was combined to 5 ml of Coomassie brilliant blue solution. Then, the absorption was detected by spectrophotometer at 595 nm and soluble protein content was calculated using the calibration curve.

To measure MDA content, 1 g of petals was ground with liquid nitrogen using a mortar and pestle. 2-Thiobarbituric acid, the reactive substance of MDA was extracted with 5 mL 20 % (w/v) TCA containing 0.5 % TBA. Absorbance of the extracts was determined at 532 and 600 nm, respectively (Dhindsa and Thorpe 1981), and MDA content was calculated using the extinction coefficient of 155 $mM^{-1}$ $cm^{-1}$.

### *Statistical analysis*

Measurements were carried out on three replicates with one flower being a replicate. Origin Version 7.5 (OriginLab corporation, Northampton, USA) was used for analysis of data. Vase life and fresh weight changes were analyzed using analysis of variance (PROC ANOVA), and means separation was determined by t-test at $P<0.05$ or $P<0.01$ for each experiment. Other data are presented as means ± standard errors (S.E.).

## Results

### *Effects of CA on the flower morphology and water absorption of cut rose*

In order to check the influences of CA on petal senescence of cut rose, 0.3 % and 0.1 % of CA were applied to cut rose in the paper. The petal edges of cut rose treated by 0.3 % and 0.1 % of CA began to be perished at the sixth

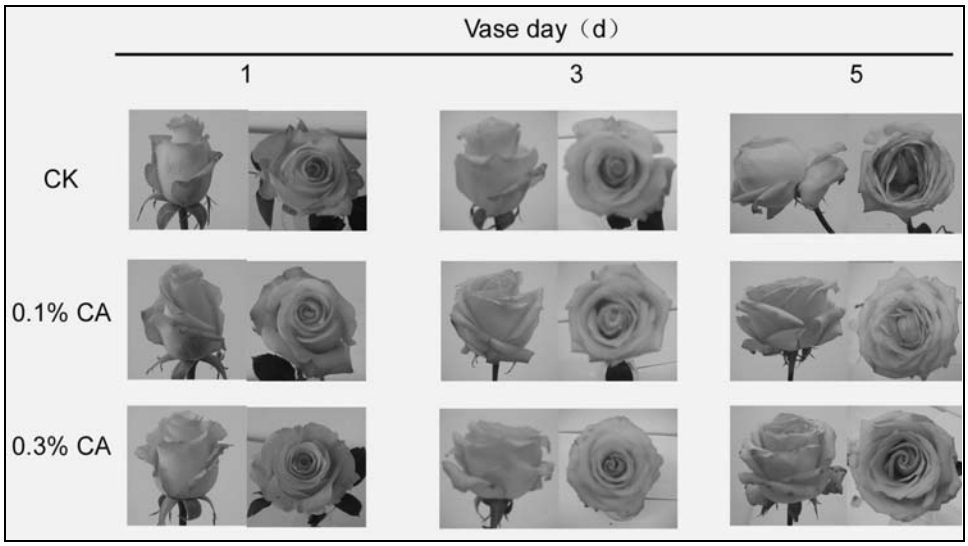



Fig. 1. Effects of CA on The flower morphology of cut rose. Cut roses were took photos from the top and side at the first, third and fifth day, respectively. The number at the top of picture indicates days in vase and the words at the left shows the treatment. The pedicle of cut roses treated by distilled water was bending at the fifth day whereas the ones of treated CA were still intact.

vase day and prolonged 3 d comparison to control. Moreover, CA markedly enhanced the morphous of petals and pedicle during the early phase of vase life (Fig. 1). However, once the aging symptom of cut rose with CA was appeared the vase life of ones was end immediately. From Fig. 2, we can conclude that vase life of cut rose with 0.3 % of CA was 11.3±0.7, prolonged 2.8 more days ($P<0.01$). Although 0.1 % of CA enhanced the vase life of cut rose by 1 d. But, compared with control, there were no difference ($P>0.05$).

To investigate the mechanism of CA on prolongation the vase life of cut rose, the value of water balance and change of fresh weight were detected. From the Table 1, water balance of control is minus at the first day whereas the one of CA is minus at the third day. Therefore, CA improved remarkably the water absorption of cut rose by 2 days. Correspondingly, fresh weight of cut rose treated by CA started to decrease at the third day and extended 2 days than one of control. Accordingly, CA, through improving the water absorption of cut rose, increased the flower morphology of cut flowers and at the final to prolong the vase life of cut roses.

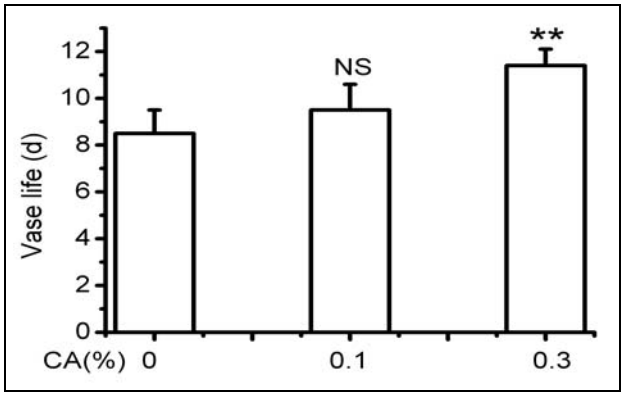



Fig. 2. Vase-life of cut rose treated with CA. Asterisks indicate these mean values that are significantly different from the controls (means separated using t-test at $P<0.01$). Vertical bars represent SE of the vase life of control (n=10), 0.1 % (n=10) and 0.3 % (n=15) of CA.

*Effects of CA on the scavenging enzyme of reactive oxygen species and superoxide anion in cut rose*

From Fig. 3A, B, C, SOD, POD and CAT activity were firstly increased and then decreased. Both activities of SOD and CAT from the third to fifth day and POD at the third day were all remarkably elevated by 0.3 % of CA whereas 0.1 % of CA had little influences on SOD, POD and CAT activity. In addition, superoxide anion, as a kind of ROS, had vital roles in process of plant senescence. Our resulted showed that there was little difference on the production

Table 1. Effects of CA on water balance value (g) of cut rose. The value of water balance was equal to water absorption besides water loss which need measure the total weight (rose, solution and Erlenmeyer flask) and rose weight every day.

| Treatment | Vase life | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| CK | −0.74 ± 0.96 | −1.48 ± 0.68 | −1.20 ± 0.16 | −1.57 ± 0.35 | −3.60 ± 0.76 |
| 0.1 % CA | 1.08 ± 0.56 ** | 0.08 ± 0.30 ** | −0.98 ± 0.47 ns | −2.30 ± 0.58 ns | −2.58 ± 0.43 ns |
| 0.3 % CA | 1.10 ± 0.30 ** | 0.44 ± 0.39 ** | −0.50 ± 0.81 ns | −0.83 ± 0.64 ns | −1.98 ± 0.85 ns |

** and ns represents significant at $P<0.01$ and not significant, respectively.

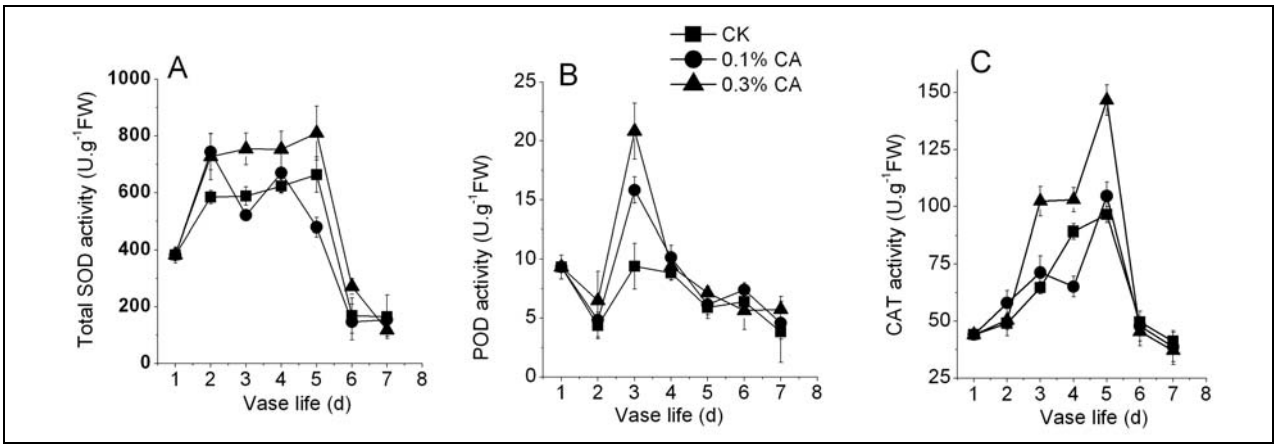



Fig. 3. Influence of CA on the activity of SOD, POD and CAT. The total activity of SOD (A), POD (B) and CAT (C) were measured every day during the early vase life of cut rose.

rate of superide anion between with both concentration of CA and not (Fig. 4A). Malonaldehyde (MDA), as the products of peroxide of membrance lipid, is the index of plants damaged by ROS. MDA increased persistently in the vase life of cut rose and was lowered to control at the second, third and sixth day (Fig. 4B). Therefore, CA delayed the ROS increase owing to boost the scavenging enzyme of ROS and has no effects on production rate of superoxide anion during the senescence process of cut rose.

*Effects of CA on content of proline and soluble protein*

To make further investigate the mechanism of CA on prolongation the vase life of cut rose, the content of proline and soluble protein were measured. The results showed that proline content was still increased at the early stage of vase life of cut rose whatever with CA or not. Same observations were reported by KUMAR et al. (2010). However, compared with the control, the proline of cut rose treated by 0.3 % CA were notable increased from the third to fifth day (Fig. 5A). Otherwise, the soluble protein content of control fluctuates during the vase life of cut rose. On the contrary, CA elevated the soluble protein content (Fig. 5B). Accordingly, through increasing the content of proline and soluble protein, CA ameliorated the flower morphology and vase life of cut roses.

## Discussion

*CA improves water deficient and prolongs the vase life of cut rose*

Vase life is mainly rely on adverse water relations videlicet absorption and loss of water, which lead to a lack of flower opening, premature petal wilting and bending of the pedicel (XUE et al. 2009). When cut rose was dissected from the whole flower tree the liquid and water which transported by sieve tube and vessel was leakaged from the nick. The sites of the nick were very easy to multiply many kinds of bacteria and fungi owe to the liquid contained anorganic ion, small peptide, polysaccharide, and so on. It's well known that the CA alone or with other components of essential oils together have strong antifungi and anti-bacterial activities (MATAN et al. 2006, CHENG et al. 2006) which leaded the tube and sieve of cut roses deviating from the blockage by sprouting of all kinds of microbes at the nick locations. Accordingly, CA,

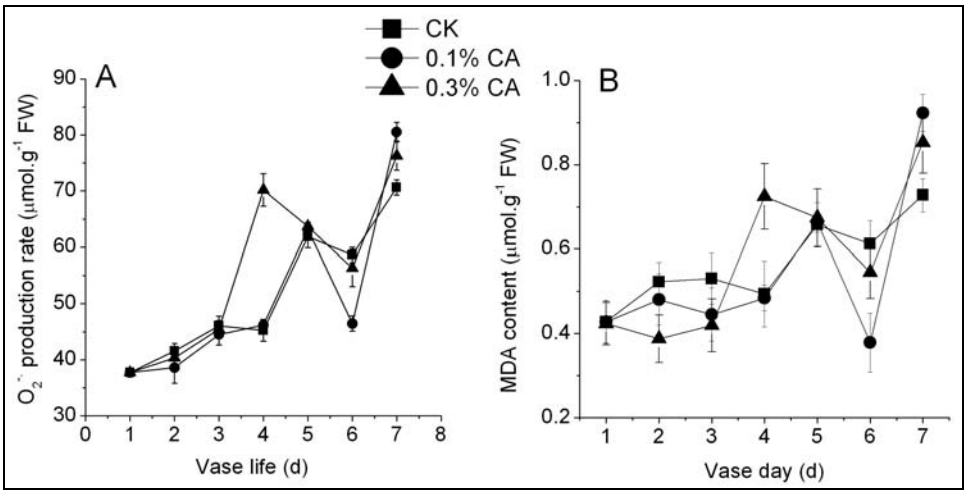



Fig. 4. Effects of CA on the content of $O_2^{\cdot-}$ and MDA. The production of $O_2^{\cdot-}$ (A) and MDA content were measured every day.

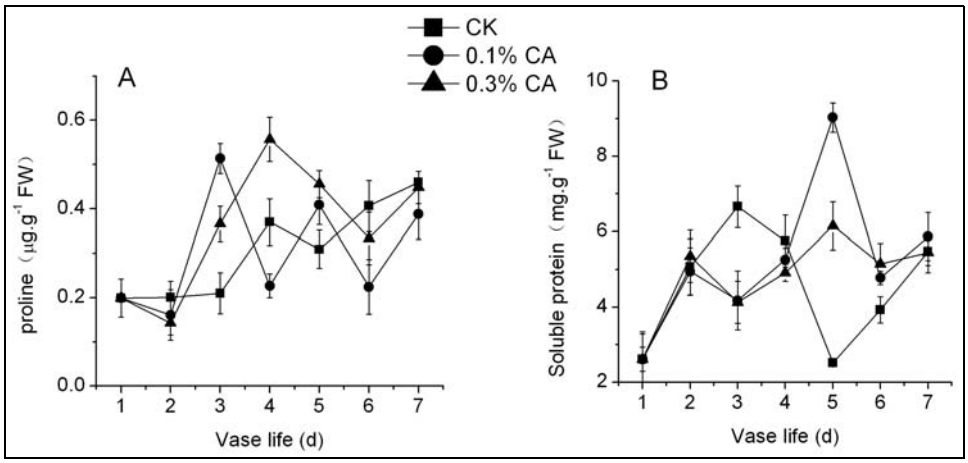



Fig. 5. Effects of CA on content of proline and soluble protein. CA had complex influences on the content of proline (A) and soluble protein (B) in cut rose.

through sustaining the tube and sieve unblocked as an antimicrobe, improved the absorption of water of cut roses (Table 1).

Otherwise, flower opening was a process of aquaporin of petals cell uptake the water from other tissues. Thus the expression of aquaporin in petal cell has a huge relation with the flowers opening. Xue reported that the expression of Rh-TIP1;1, an aquaporin expressed in cut rose, was decreased by both ethylene and water deficit (Xue et al. 2009). In the paper, CA could remarkably meliorated the water deficit of cut rose (Table 1). Therefore, CA increased the fresh weight (Table 2) and flower morphology (Fig. 1) and prolonged the vase life of cut roses 2.8 more days (Fig. 2) maybe through increasing the expression of Rh-TIP1;1 in cut rose petals.

*The relationship of CA and ROS*

ROS (reactive oxygen species) was a kind of byproducts of aerobic metabolism in plants and the light-driven photosynthetic processes in chloroplast are the main contribution to ROS production (Edreva 2005). Many kinds of ROS can react with the biological molecules such as polysaccharides, protein, DNA and membrane lipid. Superoxide anion, as a kind of important ROS, not only can oxidize the specific amino acids, such as histidine, methionine and tryptophan (Knox and Dodge 1985). But also will cause lipid peridation in a cellular environment (Halliwell and Gutteridge 1989). Our resulted showed that the production of $O_2^{\cdot-}$ was increased during the petal senescence of cut rose (Fig. 4A) which is same to the work of Kumar et al. (2007). However, 0.3 % of CA just significantly decreased the production of $O_2^{\cdot-}$ at the fourth day (Fig. 4A). Although CA has no influence on the production of $O_2^{\cdot-}$ (Fig. 4A), MDA, the products of lipid peroxidation, was decreased markedly by CA (Fig. 4B). Therefore, CA can sustain the integrity of cell membrane by other ways.

In order to protect the plant deviating from the oxygen stress damage, plant cells have many kinds of enzymes, such as SOD, CAT, POD, and so on (Sara et al. 2008; Rinalducci et al. 2008). CA increased the activities of the enzymic scavenging of ROS, such as SOD, POD and CAT during the senescence of rose petals (Fig. 3). Similar observations were also recorded by Hu et al. (2010) and Moselhy and Junbi (2010). CA, as an antioxidant, can clear ROS by inducing the increase of total activity of SOD in *Microcystis aeruginosa* (Hu et al. 2010) and activity of CAT in rats (Moselhy and Junbi 2010). Accordingly, CA elevated the activities of scavenging enzymic systems of ROS so as to departing the cut rose petals from oxidative stress damage.

Proline, as a compatible osmolyte, has ability of scavenging free radicals (Rontein et al. 2002; Matysik et al. 2002). 0.3 % of CA can moderately increase the content of proline from 2 to 5 d (Fig. 5A). Exogenous proline, as an antioxidants, increases vase life in rose by alleviating oxidative stress (Kumar et al. 2010). Therefore, CA through direct alleviating the oxidative stress in cut rose to prolong the vase life and amend flower morphology of cut rose.

Table 2. Effects of CA on change rate of fresh weight (%) of cut rose. The fresh weight of cut rose in every day was measured and normalized by the fresh weigh in first day.

| Treatment | Vase life | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| CK | 100 ± 0 | 98.98 ± 1.28 | 97.48 ± 1.06 | 98.71 ± 2.10 | 96.75 ± 2.14 |
| 0.1 % CA | 100 ± 0 | 101.47 ± 0.75 ** | 100.10 ± 0.40 ** | 98.67 ± 0.66 ns | 96.87 ± 0.55 ns |
| 0.3 % CA | 100 ± 0 | 101.51 ± 0.38 ** | 100.59 ± 0.52 ** | 99.52 ± 1.11 ns | 98.90 ± 0.86 * |

** and * represent significant at P<0.01 or P<0.05, respectively. ns is the abbreviation of not significant

## Acknowledgment

This work was supported by a start-up grant from Henan University of Technology (2009BS006).

## References

ANDRERSON, R.A., C.L. BROADHURST, M.M. POLANSKY, W.F. SCHMIDT, A. KHAN, V.P. FLANAGAN, N.W. SCHOENE and D.J. GRAVES 2004: Isolation and characterization of polyphenol type-A polymers from cinnamon with insulin-like biological activity. J. Agric. Food Chem. **52**, 65–70.

ASPINAL, D. and L.G. PALEG 1981: Proline accumulation: physiological aspects. In: PALEG, L.G. and D. ASPINAL (eds.): The physiology and biochemistry of drought resistance in plants. Academic Press, Sydney, Australia, 280–295.

BARJA, G. 2004: Free radicals and aging. Trends in Neurosci. **27**, 595–600.

CHENG, S.S, J.Y. LIU, Y.R HSUI and S.T. CHANG 2006: Chemical polymorphism and antifungal activity of essential oils from leaves of different provenances of indigenous cinnamon (*Cinnamomum osmophloeum*), Bioresource Technol. **97**, 306–312.

DHINDSA, R.S.P.P. and T. THORPE 1981: Leaf senescence: correlated with increased levels of membrane permeability and lipid peroxidation, and decreased levels of superoxide dismutase and catalase. J. Expl. Bot. **32**, 93–101.

EDREVA, A. 2005: Generation and scavenging of reactive oxygen species in chloroplasts: a submolecular approach. Agr. Ecosyst. Environ. **106**, 119–133.

HALLIWELL, B. and J.M.C. GUTTERIDGE 1989: Free Radicals in Biology and Medicine, Clarendon Press, Oxford.

HODGES, D.M., J.M. DELONG, C.F. FORNEY and R.K. PRANGE 1999: Improving the thiobarbituric acid-reactive-substances assay for estimating lipid peroxidation in plant tissues containing anthocyanin and other interfering compounds. Planta **207**, 604–611.

HU, L.B., W. ZHOU, J.D. YANG, J. CHEN. Y.F. YIN and Z.Q. SHI 2010: Cinnamaldehyde induces PCD-like death of *Microcystis aeruginosa* via reactive oxygen species. Water Air Soil. Pollut. DOI 10.1007/s11270-010-0571-1.

KIM, D.H., C.H. KIM, M.S. KIM, J.Y. KIM, K.J. JUNG, J.H. CHUNG, W.G. AN, J.W. LEE, B.P. YU and H.Y. CHUNG 2007: Suppression of age-related inflammatory NF-kappaB activation by cinnamaldehyde. Biogerontology **8**, 545–554.

KNOX, J.P. and A.D. DODGE 1985: Singlet oxygen and plants, Phytochemistry **24**, 889–896.

KUMAR, N., G.C. SRIVASTAVA and K. DIXIT 2007: Changes in the activity of superoxide dismutases during flower bud opening in Rose (*Rosa hybrida* L.). J. Hortic. Sci. Biotech. **82**, 673–678.

KUMAR, N. and G.C. SRIVASTAVA 2008: Antioxidant metabolism during petal senescence in Rose (*Rosa hybrida* L.). J. Hortic. Sci. Biotech. **83**, 755–759.

KUMAR, N., G.C. SRIVASTAVA and K. DIXIT 2008: Senescence in rose (*Rosa hybrida* L.): The role of endogenous anti-oxidant system. J. Hortic. Sci. Biotech. **83**, 125–131.

KUMAR, N., M. PAL, A. SINGH, R.K. SAIRAM and G.C. SRIVASTAVA 2010: Exogenous proline alleviates oxidative stress and increase vase life in rose (*Rosa hybrida* L. 'Grand Gala'). Scientia Hortic. **127**, 79–85.

KUROKAWA, M., C.A. KUMEDA, J. YA MAMURA, T. KAMIYAMA and K. SHIRAKI 1998: Antipyretic activity of cinnamyl derivatives and related compounds in influenza virusinfected mice. Eur. J. Pharmacol. **348**, 45–51.

MATYSIK, J., ALIA, B. BHALU and P. MOHANTY 2002: Molecular mechanisms of quenching of reactive oxygen species by proline under stress in plants. Curr. Sci. **82**, 525–532.

MAEHLY, P.C. and M. CHANCE 1954: The assay of catalase and peroxidases. In: GLUCK, D. (eds.): Methods of biochemical analysis. Interscience Publishers, New York, 357–424.

MATAN, N., H. RIMKEEREE, A.J. MAWSON, P. CHOMPREEDA, V. HARUTHAITHANASAN and M. PARKER 2006: Antimicrobial activity of cinnamon and clove oils under modified atmosphere conditions. Int. J. Food Microbiol. **107**, 180–185.

MELONI, D.A., M.A. OLIVA, C.A. MARTINEZ and J. CAMBRAIA 2003: Photosynthesis and activity of superoxide dismutase, peroxidase and glutathione reductase in cotton under salt stress. Environ. Exp. Bot. **49**. 69–76.

MITTLER, R. 2002: Oxidative stress, antioxidants and stress tolerance. Trends Plant Sci, **7**, 405–410.

MOSELHY, S.S. and H.H. JUNBI 2010: Antioxidant properties of ethanolic and aqueous Cinnamon against liver injury in rats. Int. J. Adv. Pharm. Sci. **1**, 151–155.

ORACZ, K., H.E. BOUTEAU, J.M. FARRANT, K. COOPER, M. BELGHAZI, C. JOB, D. JOB, F. CORBINEAU and C. BAILLY 2007: ROS production and protein oxidation as a novel mechanism for seed dormancy alleviation. Plant J. **50**, 452–465.

PATTERSON, B.D., E.A. MACRAE and I.B. FERGUSON 1984: Estimation of hydrogen peroxide in plant extracts using titanium(IV). Anal Biochem **139**, 487–492.

POMPODAKIS, N.E. and D.C. JOYCE 2003: ABA analogue effects on vase life and leaf crisping of cut 'Baccara' roses. Austr. J. Agric. Sci. **43**, 425–428.

RINALDUCCI, S., L. MURGIANO and L. ZOLLA 2008: Redox proteomics: basic principles for the detection of protein oxidation. J. Exp. Bot. **59**, 3781–3801.

RONTEIN, D., G. BASSET and A.D. HANSON 2002: Metabolic engineering of osmo-protectant accumulation in plants. Metab. Eng. **4**, 49–56.

SARA, R., M. LEONARDO and Z. LELLO 2008: Redox proteomics: basic principles and future perspectives for the detection of protein oxidation in plants. J. Exp. Bot. **59**, 3781–3801.

SINGH, G., S. MAURYA, M.P. DELAMPASONA and C.A. CATALAN 2007: A comparison of chemical, antioxidant and antimicrobial studies of cinnamon leaf and bark volatile oils, oleoresins and their constituents. Food Chem. Toxicol. **45**, 1650–1661.

WANG, D., J. FAN and R.S. RANU 2004: Cloning and expression of 1-aminocyclopropane-1-carboxylate synthase cDNA from rosa (*Rosa hybrida*). Plant Cell Rep. **22**, 422–429.

XUE, J., F. YANG and J. GAO 2009: Isolation of *Rh-TIP1;1*, an aquaporin gene and its expression in rose flowers in response to ethylene and water deficit. Postharvest Biol. Technol. **51**, 407–413.

YIN, D. and K. CHEN 2005: The essential mechanisms of aging: irreparable damage accumulation of biochemical side-reactions. Exp. Gerontol. **40**, 455–465.

ZHANG, S. 2009: Endogenous sulfur dioxide aggravates myocardial injury in isolated rat heart with ischemia and reperfusion. Transplantation **87**, 517–524.

Received January 17, 2011 / Accepted June 04, 2011

Addresses of authors: Hongjuan Jing (corresponding author), Tan Xiaorong, Xu Jianzhen, Zhou Guangzhou, Li Guiling, College of Biological Engineering, Henan University of Technology, Zhengzhou 450001, China, e-mail (corresponding author): hjjing@haut.edu.cn.