International Journal of Horticultural Science and Technology
Journal homepage: http://ijhst.ut.ac.ir

The Effect of Methyl Jasmonate on Postharvest Quality and Expression of *RhLAC* and *RhPIP2* Genes in Cut Rose, 'Red Alert'

Mohammad Fazli[1], Nima Ahmadi[1]*

1 Department of Horticultural Sciences, Faculty of Agriculture, Tarbiat Modares University, Tehran, Iran

ARTICLE INFO

Article history:

Received: 2 January 2023,
Received in revised form: 15 February 2023,
Accepted: 1 March 2023

Article type:

Research paper

Keywords:

Antioxidant enzymes,
Plant hormones,
Quantitative PCR,
Rosa hybrida

ABSTRACT

Adverse conditions during pre- and postharvest stages affect the longevity and quality of horticultural crops. Thus, storage conditions should be considered in marketing management, especially for cut flowers. Methyl jasmonate is a well-known signaling molecule involved in plant defense responses. Applying it as a treatment can effectively prolong the vase life of horticultural crops. The expression of Laccase gene, acting downstream of the ethylene signal transduction, can be induced by exogenous ethylene. The PIP2 gene is a major group of plasma membrane proteins that are linked to aquaporin channels. This study explored the effect of methyl jasmonate on postharvest quality and expression LAC and PIP2 genes of cut rose, cv. 'Red alert'. The results showed that methyl jasmonate improved the vase life of cut roses, although it was most effective at 0.2 µl L^{-1}. An analysis of antioxidant enzymes indicated that the highest catalase activity and peroxidase activity occurred in response to 0.2 µl L^{-1} and 0.2-0.3 µl L^{-1} methyl jasmonate, respectively, although both enzymes showed a decreasing trend during the vase life period. Proline levels increased significantly in response to 0.2 and 0.3 µl L^{-1} methyl jasmonate concentr -ations. Quantitative PCR analysis showed that all concentrations of methyl jasmonate significantly reduced the expression of PIP2 and LAC genes. The lowest expression level of PIP2 and LAC genes occurred in response to 0.2 and 0.3 µl L^{-1} methyl jasmonate, respectively. Based on our findings, the expression pattern of the Laccase gene may be regarded as a marker in evaluating postharvest characteristics of cut roses.

Abbreviations: Laccase (LAC), Methyl jasmonate (MJ), Plasma membran e protein (PIP), *Rosa hybrida* (Rh), Vase life (VL)

Introduction

Roses (*Rosa hybrida* L.) are one of the most important commercial ornamental plants. They are widely cultivated around the world for their aesthetic characteristics. To extend the qualities of post-harvest cut roses for marketing, factors affecting the longevity and quality of flowers should be considered during handling and transportation (Heo et al., 2004). Various factors affecting postharvest longevity of roses include cultivar, genetic background, cultivation conditions, harvesting operation, and post-harvest handling management (Mortensen and Gislerød, 1999).

The vase life (VL) of cut roses begins from flower harvest and continues until senescence. The VL can become limited by fungal infections and vascular occlusion (Rasouli et al., 2015). Symptoms that indicate the end of VL in cut roses include bent neck (Mortensen and Gislerød, 1999), bluing and wilting (Bredmose and Nielsen, 2004). In addition, some researchers have referred to the yellowing and abscission of leaves as symptoms of flower senescence (Fjeld et al.,

* Corresponding author's email: ahmadin@modares.ac.ir

1994).

Senescence in plants is a hormonal mechanism that affects the physiological and biochemical properties of the cellular organs and composition. These changes may be implicit as an increase in the expression of hydrolysis enzymes, breaking down macromolecules, raising cellular respiration rate, decreasing phospholipids, protein content, and membrane stability (Borochov and Woodson, 1989). Moreover, senescence usually accelerates the activity of reactive oxygen species such as hydrogen peroxide and hydroxyl which are produced in organelles. The cell membrane is mostly exposed to free radicals during senescence and becomes more susceptible to damage because of reactive oxygen species (Lynch et al., 1985).

Jasmonates play an important role in the defense mechanisms of plants by countering biotic and abiotic stress conditions (Wasternack and Hause, 2013). Active natural or synthetic jasmonate compounds such as jasmonic acid and its ester derivatives have a direct role in protecting against diseases (Meir et al., 1998). Their mechanism of protection is by increasing the activity of antioxidant compounds (Hasagawa et al., 2000). Jasmonic acid reportedly increased in response to external stimuli such as mechanical injury, pathogens, and osmotic pressure. Methyl jasmonate (MJ) is the volatile form of jasmonic acid. It is a well-known molecular signaling agent in plant defense responses (Wasternack and Hause, 2013).

Ethylene is a plant hormone that plays a key role in regulating the senescence process in many plant organs, including fruits, leaves, and flowers, as well as the senescence and abscission of floral buds (Ahmadi et al., 2008). In most climacteric flowers, the final stage of wilting is associated with a positive feedback effect of ethylene, which affects the marketability of cut flowers (Yang and Hoffman, 1984). Aquaporin channels are the primary pathway of water transport from biological membranes, which are involved in many plant processes such as cell growth, organ movement, and cell elongation. PIP1 and PIP2 are two major groups of plasma membrane proteins (PIPs) that are linked to aquaporin channels. The expression of PIP genes can be regulated by abiotic stress and plant hormones. Usually, PIP2 plays a greater role in water transport than PIP1 (Ma et al., 2008). For the first time, Laccase (LAC) gene expression was reported in miniature roses under exogenous ethylene treatments (Ahmadi et al., 2008). According to a study, ethylene-sensitive cultivars expressed a higher level of the LAC gene than ethylene-tolerant ones (Ahmadi et al., 2009). Moreover, applying 1-MCP resulted in an extended longevity of cut roses through the suppression of LAC expression. Accordingly, the LAC gene acts downstream of the ethylene signal transduction pathway (Daneshi Nergi and Ahmadi, 2014).

In this research, the effects of MJ on post-harvest characteristics of cut roses, cv. 'Red Alert', were studied. Moreover, due to the importance of the LAC gene in downstream ethylene signals, its transduction pathway, and the effect of the PIPs gene in aquaporin channels, the expression of LAC and PIP2 genes were evaluated under MJ treatment. The expression was measured via q-RT-PCR.

Material and Methods

Plant materials and experimental conditions

Cut rose flowers (*Rosa hybrida* L., cv. 'Red Alert') were harvested from a commercial greenhouse, and transported to the lab within 2 h. They were promptly selected for apparent quality. Healthy cut flowers were re-cut to 45 cm in length. The stem bases were continuously held in vases with a 400 ml vase solution (200 mg L^{-1} 8-hydroxyquinoline and 3% sucrose). The experiments were run at 18±2 °C, 70% ± 5 relative humidity, 15 µmol m^{-2} s^{-1} light intensity, and a 12/12 h day/night cycle.

Exogenous MJ treatment

This research was conducted as a factorial experiment in a completely randomized design, with five treatment levels, including 0 (distilled water as control), 20 µl L^{-1} ethanol, 0.1, 0.2, and 0.3 µl L^{-1} MJ. Three replications were used in each treatment group. All MJ treatments were applied with 20 µl L^{-1} ethanol. The other factor was the time of sampling, as 0, 3, 6, and 9 days after the treatment. There were 75 cut flowers, 15 vases, and 5 flowers per vase. The vases were placed in glass chambers. The required amount of MJ and ethanol or distilled water were poured onto a filter paper. The lead of each chamber was hermetically sealed. After fumigating for 24 h, vase containers of cut flowers were transferred from glass chambers on the lab bench under the same conditions.

Evaluation of display quality characteristics

Flower longevity was determined by petal discoloration and wilting. The longevity was determined by considering at least three petals (Possiel, 2008). Relative fresh weight was evaluated according to a method by He et al. (2006). The anthocyanin content was determined pursuant to Mori et al. (1993). Chlorophyll content was measured according to Arnon

(1967). The evaluation of catalase was done by preparing a reaction mixture containing crude extract, 25 mM sodium phosphate buffer (pH 6.1) and 10 mM H2O2, while recording the reduction of absorbance at 240 nm (Rahmani et al., 2015). Peroxidase activity was measured as described by Sadeghi Raviz et al. (2016). Total protein concentrations were evaluated according to Bradford (1976) and the amount of proline in petals was calculated according to Bates et al. (1973).

RNA isolation and DNase treatment

Samples were collected from petals, 48 h following the treatment. They were immediately frozen in liquid nitrogen and stored at -80 °C until the extraction of RNA. Total RNA was isolated from about 100 mg powder of petal sample using the InviTrap® Spin Plant RNA Mini Kit (Stratec Co.) according to the manufacturer's instructions. RNA quantity and quality were evaluated by measuring the absorbance at 260/280 nm ratio (Epoch® Microplate Spectrophotometer) and running on 1% agarose gel visualized by green viewer™. To remove any genomic DNA, RNA samples were treated with DNase I (Fermentas Co.). This was followed by adding 1 U of DNase I and 1 µl of 10 × DNase reaction buffer (10 mM Tris-HCL, 2.5 mM MgCl2, 0.5 mM CaCl2, pH 7.6) to each 1 µg RNA sample. They were incubated in a thermocycler (Bio-Rad Co.) at 37 °C for 30 min. To eliminate the residues of the DNase enzyme, 1 µl of 50 mM EDTA was added to each RNA sample, followed by incubation at 65 °C for 10 min. To avoid any RNA degradation, the samples were stored at -20 °C for a short period and at -80 °C for longer periods.

cDNA synthesis and Real-Time PCR assay

In this evaluation, 1 µg DNA-free RNA was reversely transcribed using 10 µl buffer-mix (2x) (RT buffer, 1mM dNTP mixture, 8 mM $MgCl_2$ and Oligo dT), 2 µl enzyme mix (thermo stable H-minus MMLV and RNase inhibitor), and DEPC-treated water (up to 20 µl). The reaction solution was incubated at 25 °C and 47 °C for 10 and 60 min, respectively. The reaction was stopped by heating the solution at 85 °C for 5 min and immediately chilling it on ice.

To quantify mRNA levels, real-time-PCR assays were performed using the Rotor-Gene 6000 real-time thermocycler (QIAGEN Inc. USA). The PCR reaction mixture was made up to a volume of 20 µl, containing 100 ng cDNA template, 10 µl Real-Time PCR Master Mix 2x (BioFACT Co.). It contained the SYBR® Green, 2 µl forward and reverse primers (Table 1), and the final volume was adjusted to 20 µl in dsH_2O. After 15 min of incubation at 95 °C, the cDNA was amplified by 45 three-step cycles: 20 s at 95 °C, 1 min at 58 °C, and 2 min at 72 °C. To normalize target gene expression among all samples, the expression level of Ubiquitin C (UBC) as a housekeeping gene was detected for each sample concomitantly along with specific gene primers. The specificity of the PCR amplification was checked with a melting curve analysis (from 70 to 94 °C), following a final cycle of the PCR.

Table 1. Gene-specific primer pair used for real-time RT-PCR.

Gene	Accession number	Primer name	Sequence
RhLAC	EU603403	Forward	GAACCACCCCATTGATGTTC
		Reverse	TGGCAGTCAGCATAAACCAA
RhPIP2	EU572717	Forward	GGCATGATCTTTGTCCTCGT
		Reverse	AATGGTCCGACCCAGAAGAT
RhUBC	XM_024316802	Forward	CCAAAGGTTGCATTCAGGAC
			ACTTCTGGGTCCAGCTCCTT

Experimental design and data analysis

The experiment was conducted as a factorial experiment in a completely randomized design with 3 replications. One of the factors was the MJ treatment and the other was the day count after the treatment. SAS 9.1 statistical analysis software was used for data analysis. A normalization test was performed and mean values were compared using the LSD test ($P \leq 0.05$ and $P \leq 0.01$). The mean values and the standard deviation ($\pm$SD) of the parameters were reported. The analysis of real-time data was performed using the Rotor-Gene software (version 6.1.81). The relative quantification of transcript abundance of target genes in individual plant samples was determined by the 2-ΔΔct method.

Major changes of various genes, relative to the control, were calculated for each replicate of each sample (Livak and Schmittgen, 2001).

Results

The effect of MJ treatments on vase life, and effect of MJ treatments and times on relative fresh weight

The results showed that the MJ treatment significantly affected the VL ($p \leq 0.01$). The highest VL was observed in cut flowers treated with 0.2 µl L^{-1} MJ, extending the VL to 12.6 days, while it was 9 days in the control. Treatments of flowers with 0.1 and 0.3 µl L^{-1} MJ did not show any significant difference in the VL, although their VL was higher than the control. These concentrations increased the VL to 10.6 and 10 days, respectively. Ethanol increased the VL to 9.6 days, but its effect was not statistically different from that of the control (Fig. 1).

Both MJ concentrations and time significantly affected the relative fresh weight of cut flowers ($P \leq 0.01$). The highest relative fresh weight (96.14%) was recorded in cut flowers treated with 20 µl L^{-1} ethanol and no significant difference was observed between the control and the different concentrations of MJ in this regard. The highest relative fresh weight (107.44%) was observed on day 3 and the lowest (83.58%) was observed on day 9 after harvest, with no significant difference between days 0 and 6 (Fig. 2).

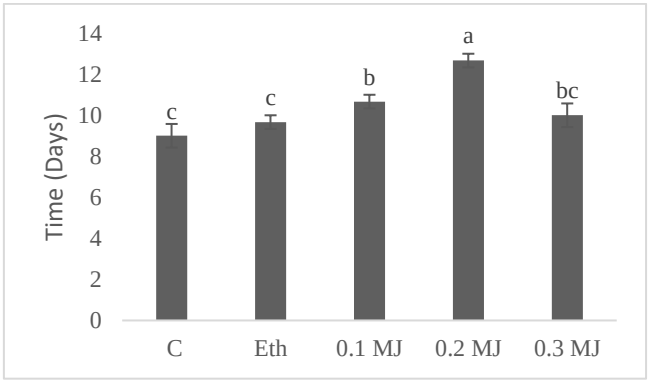
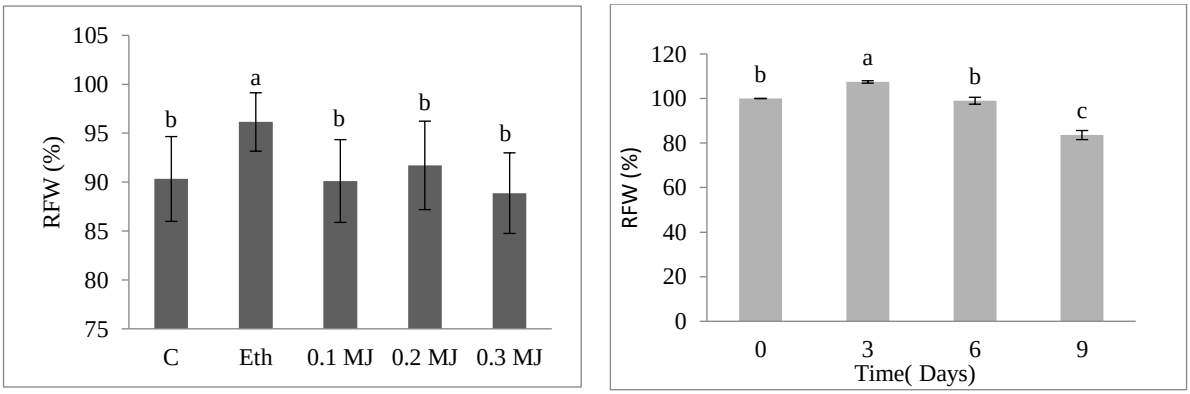


Fig. 1. The effect of MJ on the vase life. Treatments with the same letter do not have significant differences. Vertical bars represent standard deviations (n = 3). Comparison of means based on LSD test at 1% level ($P \leq 0.01$). C: Control, Eth: Ethanol, MJ: Methyl jasmonate 0.1, 0.2 and 0.3 µl L^{-1} concentrations.

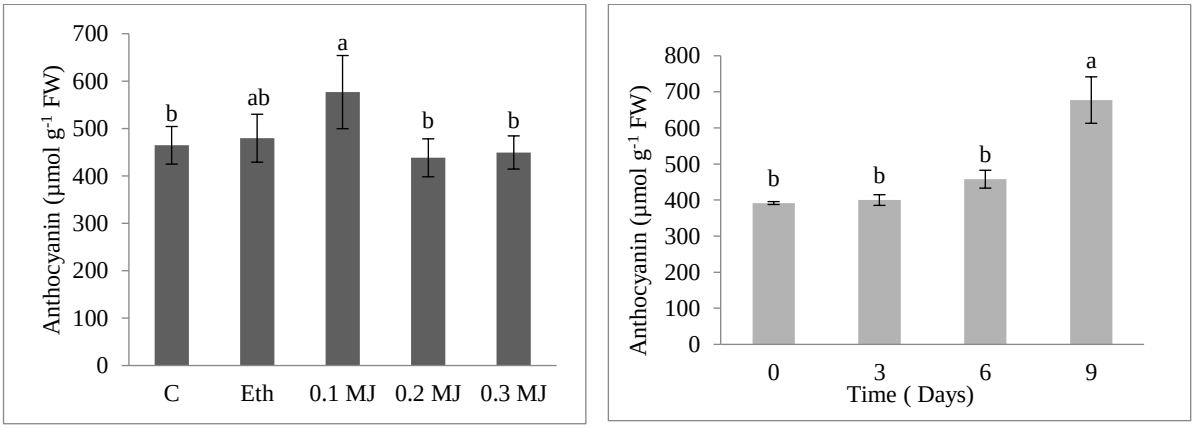


(**a**) (**b**)

Fig. 2. Relative fresh weight (%): (a) The effect of MJ on the relative fresh weight. (b) The effect of time on the relative fresh weight. Treatments with the same letter do not have significant differences. Vertical bars represent standard deviations (n = 3). Comparison of means based on LSD test at 1% level ($P \leq 0.01$). C: Control, Eth: Ethanol, MJ: Methyl jasmonate 0.1, 0.2 and 0.3 µl L^{-1} concentrations.

The effect of MJ treatments and times on pigments

The MJ treatment affected the petal anthocyanin content ($P \leq 0.05$). It was also significantly affected by time ($P \leq 0.01$). The highest amount of anthocyanin was found in response to 0.1 µl L^{-1} MJ, without any significant difference with the ethanol treatment. The maximum concentration of anthocyanin was determined 9 days after treatment with no significant difference between days 0, 3, and 6 (Fig. 3). In this experiment, there was no significant difference between the treatment, time, and their interaction on total chlorophyll, chlorophyll a, b and chlorophyll a/b ratios.



(**a**) (**b**)

Fig. 3. Anthocyanin contents (µmol g^{-1} FW): (a) The effect of MJ on the anthocyanin. (b) The effect of Time on the anthocyanin. Treatments with the same letter do not have significant differences. Vertical bars represent standard deviations (n = 3). Comparison of means based on LSD test at 5% level ($P \leq 0.05$) in (a) and 1% level ($p \leq 0.01$) in (b). C: Control, Eth: Ethanol, MJ: Methyl jasmonate 0.1, 0.2 and 0.3 µl L^{-1} concentrations.

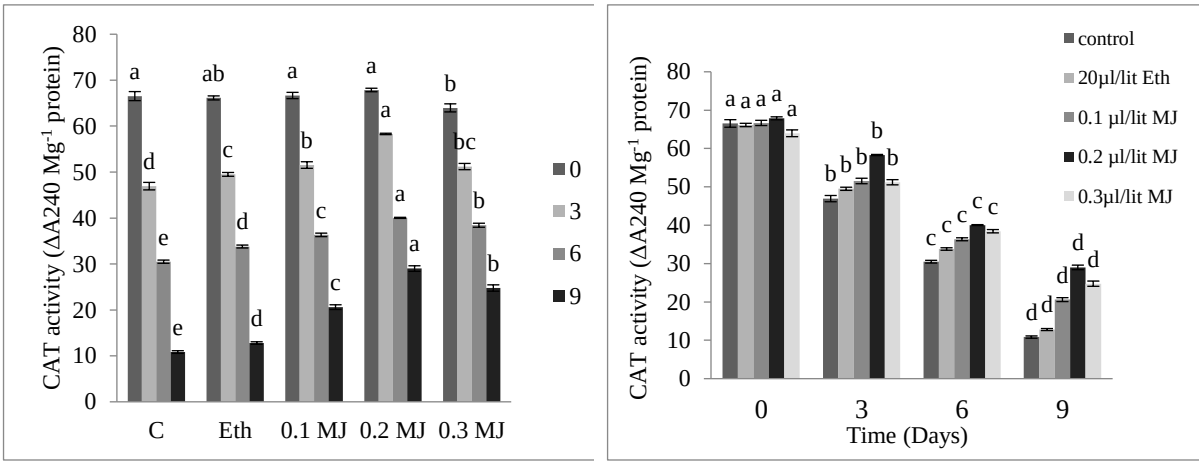
The effect of MJ treatments and times on antioxidant enzyme activity

Data showed that the effects of MJ treatment and time, as well as the interaction between treatment and time were significant on catalase activity ($P \leq 0.01$). On day 0, there was no significant difference in the amount of catalase activity on days 3, 6, and 9 after harvest. The highest and lowest concentration of catalase activity occurred in response to 0.2 µl L^{-1} MJ and control treatments. The amount of catalase activity decreased gradually through the VL (Fig. 4).

Also, significant differences were observed from the effects of treatment, time, and interaction between treatment and time on peroxidase activity ($P \leq 0.01$). On day 0 after harvest, no significant difference in peroxidase activity was observed between treatments. The application of 0.3 and 0.2 µl L^{-1} MJ contributed to the highest peroxidase activity on day 3 after harvest. However, on days 6 and 9, the highest activity occurred in response to 0.3 and 0.2 µl L^{-1} MJ. Furthermore, on 3, 6, and 9 days after harvest, the lowest peroxidase activity was similarly determined in the control treatments. The amount of peroxidase activity showed a decreasing trend through the VL (Fig. 5).

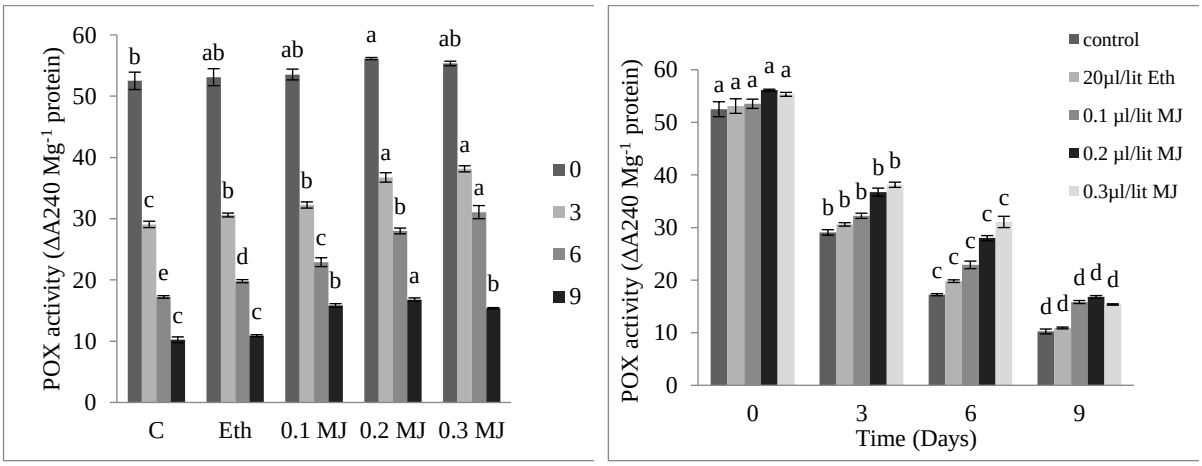
The effect of MJ treatments and times on proline contents

The observations showed that the effects of treatment, time, and interaction effects of treatment and time were significant ($P \leq 0.01$) on proline content. On day 0 after harvest, no differences were found in the proline content, compared to day 3 after harvest. The highest proline content was found in 0.3 and 0.2 µl L^{-1} MJ treatments and the lowest in the control treatment. The highest proline content was measured at day 6 after harvest, under the effect of 0.3 µl L^{-1} MJ. The lowest was observed in the control. The highest amount of proline in petals was observed on day 9 after harvest under the effect of 0.3 and 0.2 µl L^{-1} MJ treatments. The lowest amount was acquired in the control treatment. Proline content in all applied treatments showed a significant increase in the VL (Fig. 6).



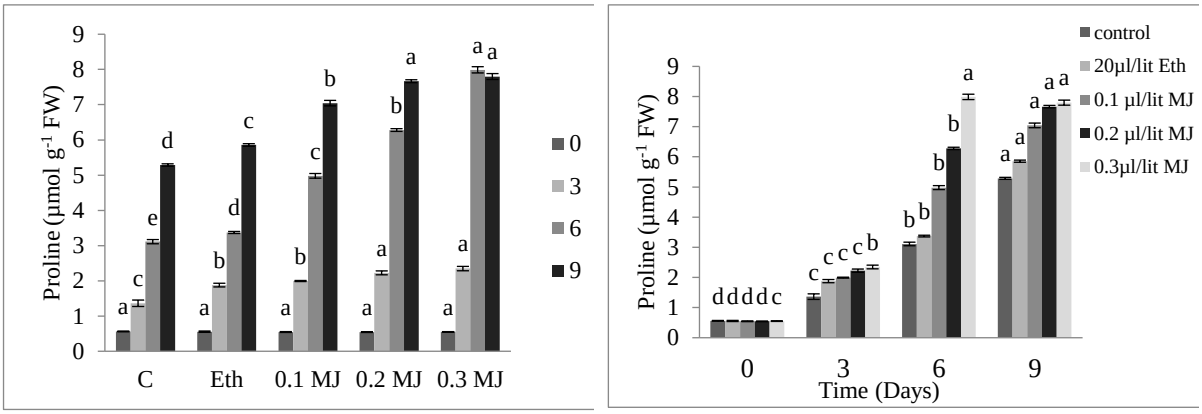
(**a**) (**b**)

Fig. 4. Catalase activity (ΔA240 Mg^{-1} protein): (a) and (b) interaction between MJ and time on catalase activity. Treatments with the same letter do not have significant differences. Vertical bars represent standard deviations (n = 3). Comparison of means based on LSD test at 1% level (P≤0.01). C: Control, Eth: Ethanol, MJ: Methyl jasmonate 0.1, 0.2 and 0.3 µl L^{-1} concentrations.



(**a**) (**b**)

Fig. 5. Peroxidase activity (ΔA240 Mg^{-1} protein): (a) and (b) Interaction between MJ and time on peroxidase activity. Treatments with the same letter do not have significant differences. Vertical bars represent standard deviations (n = 3). Comparison of means based on LSD test at 1% level (P≤0.01). C: Control, Eth: Ethanol, MJ: Methyl jasmonate 0.1, 0.2 and 0.3 µl L^{-1} concentrations.

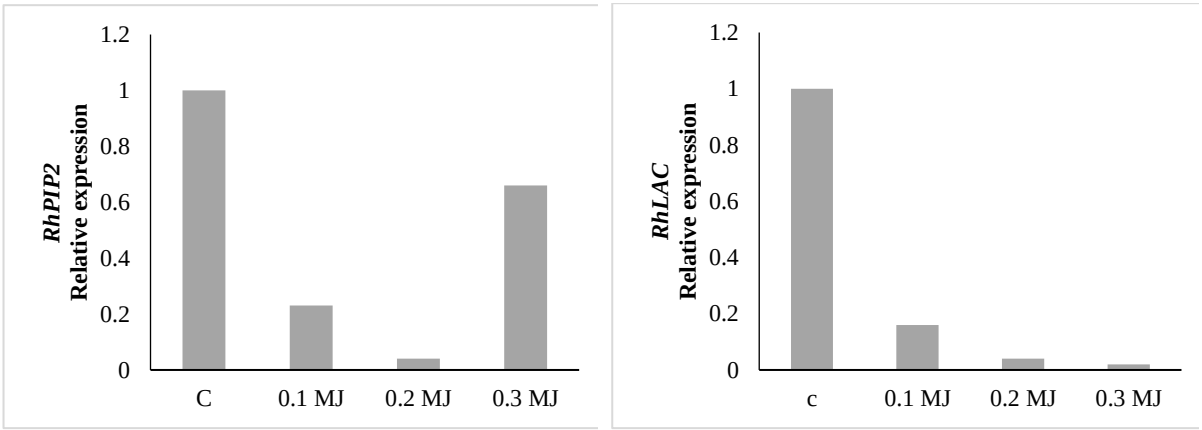


(**a**) (**b**)

Fig. 6. Proline contents (µmol g^{-1} FW): (a) and (b) Interaction between MJ and Time on proline content. Treatments with the same letter do not have significant differences. Vertical bars represent standard deviations (n = 3). Comparison of means based on LSD test at 1% level (P≤0.01). C: Control, Eth: Ethanol, MJ: Methyl jasmonate 0.1, 0.2 and 0.3 µl L^{-1} concentrations.

Evaluation of RhPIP2 and RhLAC expression

Quantitative analysis of *RhPIP2* expression showed that all concentrations of MJ significantly reduced the expression of this gene. The lowest expression level was observed in the treatment of 0.2 µl L^{-1} MJ. Like the *RhPIP2* gene, the quantitative analysis of the *RhLAC* gene expression showed that the MJ at all concentrations resulted in a significant decrease in the expression of this gene. Increasing the concentration of the MJ treatment resulted in a decrease in the *RhLAC* gene expression, whereas the lowest expression level was observed under the effect of 0.3 µl L^{-1} MJ (Fig. 7).



(**a**) (**b**)

Fig. 7. Changes in *RhPIP2* (a) *RhLAC* (b) genes expression pattern under different MJ concentrations. Normalization was carried out by the expression levels of the UBC housekeeping gene. C: Control, MJ: Methyl jasmonate 0.1, 0.2 and 0.3 µl L^{-1} concentrations.

Discussion

MJ reportedly stimulates the expression of genes involved in abscisic acid synthesis. It enhances the relative fresh weight. When abscisic acid is present, vase solution can be absorbed more readily and stomata are closed, so the fresh weight is not lost (Kanani and Nazarideljou, 2017). There are many reasons for the prolonged

VL, which seem to be related to the alleviation of free radicals by antioxidant enzymes (van Doorn, 2012). Our observations showed that the MJ treatment increased the activity of antioxidant enzymes (Fig. 4 and Fig. 5). Free radicals damage lipid, protein, and nucleic acid and ultimately cause cell damage (Saeed *et al.,* 2014). MJ reportedly prolonged the VL of tuberose because of a relative fresh weight gain in tuberose flowers. It enhanced the antioxidant enzyme activity and improved the uptake of the vase solution (Kanani and Nazarideljou, 2017). Exogenous MJ delayed the senescence of cut rose 'Meivildo' petals, which could be attributed to the stimulation of sucrose withdrawal from the leaves to the petals (Horibe *et al.,* 2013). Exogenous MJ increased the VL of gerbera, due to its relative fresh weight gain and an increase in antioxidant enzyme activity (Sadeghi raviz *et al.,* 2016).

In many plants, exogenous treatment of MJ causes drastic changes in secondary metabolites. Exogenous treatment of MJ on cut rose has been reported to increase anthocyanin content (Ram and Singh, 2013). Also, MJ treatment on 'Fuji' apples increased the amount of anthocyanin pigments (Rudell *et al*., 2002). In the current experiment, there was no significant difference between the effects of treatment, time, and their interaction on total chlorophyll, chlorophyll a, b and chlorophyll a/b ratios. Contrary to our results, Rudell *et al.* (2002) reported that MJ increased chlorophyll b in 'Fuji' apples, whereas it had no effect on chlorophyll a, thereby confirming our findings. Furthermore, Wu et al. (2012) reported a significant increase in total chlorophyll concentration in cauliflower under the effect of MJ, which contradicted our results.

Antioxidant enzymes play an important role in the enhancement of VL. Specifically, MJ increased the activity of peroxidase and catalase in cut tuberose flowers (Kanani and Nazarideljou, 2017). Putrescine, jasmonate, salicylate, spermine, and spermidine treatments enhanced catalase and superoxide dismutase enzymes in cut iris (Ahmad and Tahir, 2016). Silver nanoparticles increased the catalase, peroxidase, and superoxide dismutase enzymes activity in 'First Red' rose (Hassan *et al.,* 2014). In all of them, increasing the activity of antioxidant enzymes enhanced the postharvest longevity. Given an increase in the activity of antioxidant enzymes in response to the MJ, it seems that MJ can delay petal senescence and improve VL by increasing antioxidant enzyme activity. These results are in line with previous findings that showed the antioxidant defense system in plants reduces the amount of reactive oxygen species and oxidative stress (Zhou *et al.,* 2014). Strengthening the antioxidant system of plants in response to the external application of compounds such as jasmonates and salicylates can reduce the effects of free radicals (Kang and Saltveit, 2002). MJ increased antioxidant enzyme activities and free radical scavenging capacities (Wang, 2006).

The proline content in all treatment groups showed a significant increase through the VL. The results of one experiment showed that applying proline as an external treatment on post-harvest cut rose 'Grand Gala' increased the VL (Kumar *et al.,* 2010), indicating the role of proline in improving the VL.

It was reported that ethylene reduced PIP2 levels (Ma et al., 2008), although there is a controversial report on the expression of aquaporins genes under ethylene treatment in a variety of organs in different plants (Daneshi Nergi and Ahmadi, 2014). Perhaps the pattern of *RhPIP2* expression under the MJ treatment can be concentration-dependent. The development of petals occurs primarily due to the growth of cells rather than the enlargement of cells due to a rapid increase in water absorption (Guterman *et al.,* 2002). Ethylene significantly reduces cell growth in petals. Also, it reduces the water content of petals. As a result, PIPs may be involved in the process of ethylene growth inhibition in petals. PIP2 is usually more active in water transport than PIP1 (Ma *et al.,* 2008). An increase in the expression of *PIPs* in Arabidopsis has been reported to be associated with increased growth processes such as increased root growth and increased cell growth (Javot *et al.,* 2003), anther opening (Bots *et al.,* 2005), and leaf growth (Moshelion *et al.,* 2002). According to the results, a significant relationship can be observed between the vase life and the relative expression of *RhPIP2*. As a result, MJ increased the vase life and decreased the *RhPIP2* relative expression, compared to the control. It can be concluded that MJ delayed senescence by inhibiting cell growth and development.

The LAC gene plays downstream of the ethylene signal transduction pathway and its expression is affected by ethylene. Thus, in contrast to ethylene, any inhibitor of ethylene that binds to the receptor such as 1-MCP can suppress LAC (Ahmadi et al., 2008; Daneshi Nergi and Ahmadi, 2014). Ethylene has also been reported to increase LAC expression in various plant organs of various miniature rose genotypes (Ahmadi *et al.,* 2009). Our results showed that MJ improved the vase life and partially maintained flower quality. Furthermore, the *RhLAC* gene expression was significantly reduced under the effect of MJ, compared to the control. The effect of MJ on vase

life and its suppressive effect on *RhLAC* expression could be related to the prevention of endogenous ethylene biosynthesis or the suppression of ethylene action by the MJ treatment. This assumption is supported by previous findings that reported LAC could be involved in accelerating the senescence of plant organs in response to ethylene (Ahmadi *et al.,* 2008, 2009).

Conclusions

Cut rose longevity and quality preservations must be considered in postharvest management. This study showed that the vase life of cut roses was improved by MJ. The mechanism of this enhancement was by raising the concentration up to 0.2 µl L^{-1}. It was revealed that MJ increased the activities of antioxidant enzymes, such as catalase, peroxidase, and proline content. Furthermore, MJ suppressed the expression of *RhLAC*. In earlier findings, ethylene reportedly increased *RhLAC* expression. MJ partially prevented the harmful effects of ethylene, thereby improving the postharvest life of cut roses. Applying MJ on cut roses may benefit their postharvest longevity by suppressing the LAC gene and inducing antioxidant enzyme activity. As a result, the MJ treatment may be applied effectively on cut roses during postharvest handling.

Acknowledgments

The authors would like to thank Dr. Alireza Babaei for providing plant materials and Dr. Ali Mokhtassi-Bidgoli for his statistical advice. This research was supported by Tarbiat Modares University, Tehran, Iran.

Conflict of interest

The authors indicate no conflict of interest for this work.

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