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Ascorbic acid reduces chilling injury in anthurium cut flowers during cold storage by increasing salicylic acid biosynthesis

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Highlights

- Storage at 4 ºC caused chilling injury in anthurium flowers.
- Ascorbic acid treatments extended flowers vase-life.
- Ascorbic acid treatments increased endogenous biosynthesis of salicylic acid.
- Antioxidant activity of flowers was increased by ascorbic acid treatments.

Abstract

Chilling injury (CI) and vase-life reduction are the dominant issues of anthurium cut flowers storage under cold conditions. In the present study, the influence of post-harvest treatments of ascorbic acid (AsA) at concentrations of 0, 1, 2 and 4 mM by two application methods included pulse and spraying on maintainability of anthurium cut flowers (cv. 'Fire Glow') was evaluated under temperature of 4 °C during 0, 7, 14 and 21 d of storage. Results demonstrated that increasing storage duration led to more CI and lower flowers quality. Application of AsA treatments effectively reduced CI and extended vase-life of anthurium cut flowers during cold storage. Pulse treatment was more effective than spraying method on maintainability of flowers, so that the lowest CI and highest vase-life was observed in pulse-treated flowers at 2 mM. Also, the lowest electrolyte leakage, malondialdehyde content, hydrogen peroxide content and polyphenol oxidase, lipoxygenase and phospholipase D enzymes activity and the highest total phenol content, radical scavenging activity and catalase, superoxide dismutase, ascorbate peroxidase and phenylalanine ammonia-lyase enzymes activity were recorded in flowers treated with this treatment. Obtained results indicated that AsA-treated flowers showed the higher endogenous contents of AsA and salicylic acid (SA) than the control and AsA and SA content of pulse-treated flowers was higher than those of sprayed flowers. AsA treatments probably increased the endogenous content of AsA and biosynthesis rate of SA which led to enhanced radical scavenging activity and reduced CI in treated flowers during cold storage. In conclusion, AsA pulse-treatment at 2 mM could be introduced as superior treatment and using that is recommendable as suitable method to enhance post-harvest chilling tolerance of anthurium cut flowers during cold storage under 4 °C.

Introduction

Anthurium (*Anthurium andraeanum* L.) is an ornamental plant belonging to Araceae family and is native to tropical regions. Anthurium is the second most important tropical flower in global floriculture industry just after the orchid flower. Although it is also produced as potted flower, its cut flower industry is more economically important (Gopaulchan et al., 2013). Storage under cold conditions is the one of solutions to extend maintainability of horticultural crops which is associated with reduction of ethylene biosynthesis and respiration rate and delaying in crops aging (Luengwilai et al., 2012). Since anthurium is native to tropical regions, its cultivation and storage under temperatures of lower than 12 °C will cause appearance of chilling injury (CI) symptoms (Solaimani Aghdam et al., 2015). Spathe browning induced by low temperature storage is the one of most important physiological disorders of anthurium at

post-harvest stage (Soleimani Aghdama et al., 2016a, Soleimani Aghdam et al., 2015). Studies have shown that post-harvest CI in anthurium cut flowers is associated with spathe browning, increasing electrolyte leakage (EL) and malondialdehyde (MDA) accumulation (Solaimani Aghdam et al., 2016b). High rates of unsaturated/saturated fatty acids, high levels of cellular energy, low activity rate of lipoxygenase (LOX) and phospholipase D (PLD) enzymes and enhanced activities of antioxidant enzymes are positively effective on reduction of membrane damages and preventing the reactive oxygen species (ROS) accumulation and will increase chilling tolerance threshold of plants (Cao et al., 2009; Soleimani Aghdama et al., 2016a, Soleimani Aghdam et al., 2015). Also, enhancing post-harvest chilling tolerance of different crops is positively correlated with increasing antioxidant enzymes activities (Cao et al., 2009; Soleimani Aghdam et al., 2019, Soleimani Aghdama et al., 2016a, Soleimani Aghdam et al., 2016b). Evaluation of anthurium cut flowers characteristics during storage under temperature of 4°C demonstrated that CI rate and flower senescence process are accelerated by increasing the activity of LOX and PLD enzymes (Soleimani Aghdam, 2016a). Therefore, researchers are always looking for suitable solutions to reduce chilling damages and extending vase-life of this flower.

Studies have demonstrated that proper post-harvest management and applying different pre- and post-harvest treatments are the most important solutions to decrease low temperature damages and can extend maintainability of different horticultural crops during cold storage (Ketrodsakul et al., 2016, Suttirak and Manurakchinakorn, 2010; Mohammadi et al., 2020, Mohammadi et al., 2021). SA, gamma-aminobutyric acid (GABA) and melatonin are some of evaluated compounds to decrease chilling damages of anthurium cut flowers during cold storage. AsA is widely used compound as an environmentally safe antioxidant to maintain the quality of stored crops (Balouchi et al., 2012, Sogvar et al., 2016, Zheng et al., 2021). Although the mechanisms of action of this organic compound are not well known so far, its post-harvest application will lead to enhancing antioxidant activities and membrane stability and maintaining post-harvest qualitative characteristics of different crops (Davey et al., 2000, Zheng et al., 2021). AsA is a strong reducing compound which can react with oxidative agents such as ROS and neutralize their negative effects (Zheng et al., 2021, Kim et al., 2002). Mitochondrion organelle is the main place of AsA biosynthesis and different pathways have been reported for its production in plant cells. L-galactose is the most important pathway for AsA biosynthesis which is also known as Smirnoff-Wheeler pathway (Zheng et al., 2021). AsA as an antioxidant compound plays important roles in neutralizing ROS effects and reducing

oxidative damages. Since AsA is a water-soluble compound, it can control ROS effects inside and outside of the cells. This compound is remarkably sensitive to chemical and enzymatic oxidation during storage of horticultural crops (Lee and Kader, 2000). AsA turns into its oxidized form (dehydroascorbic acid) simultaneously with the reduction of oxygen concentration around the crop. This oxidation reaction reduces the concentration of environmental oxygen and turns AsA into a strong antioxidant agent (Lamikanra and Watson, 2001). AsA not only is a strong antioxidant but also plays many important and vital roles in flowering, photosynthesis, tolerance to abiotic stresses and some plant growth processes such as cell division, cell wall expansion, cell aging and response to plant pathogens (Pignocchi and Foyer, 2003). AsA can directly scavenge some ROS such as superoxide and hydroxyl and acts as specific electron donor for ascorbate peroxidase enzyme to reduce H_2O_2 to water (Davey et al., 2000).

According to reports, AsA can considerably decrease chilling damages to fatty acids and proteins by scavenging the ROS (Kim et al., 2002). Son et al. (2001) reported that AsA treatment could significantly decrease enzymatic browning. Also, some similar results were obtained in the other conducted researches on different crops (Lamikanra and Watson, 2001, Guerrero-Beltran et al., 2005). In the other study, the effect of some organic acids on polyphenol oxidase enzyme (PPO) activity and browning process was evaluated in some fruit and vegetable crops. Results indicated that AsA and oxalic acid were the most effective compounds to prevent tissue browning (Suttirak and Manurakchinakorn, 2010). Also based on some reports, AsA as an enzymatic cofactor plays important roles in some biochemical reactions and acts as antioxidant and electron transfer factor in the chloroplast membrane (Ivanov, 2014, Budiarto, 2019). The results of some conducted researches showed that exogenous application of AsA will lead to increasing endogenous content of AsA and vast-life of gerbera (*Gerbera jamesonii*) (Mehdikhah et al., 2016), gladiolus (*Gladiolus* spp.) (Ravanbakhsh et al., 2016) and chrysanthemum (*Chrysanthemum morifolium*) (Budiarto, 2019). The purpose of the current study was to evaluate the effect of post-harvest treatments of AsA through two different application methods included spraying and pulse treatment on chilling tolerance rate and post-harvest qualitative characteristics of anthurium cut flower during cold storage at 4°C.

Section snippets

Treatments

The experiment was carried out at Ilam University (Ilam, Iran), Shahid Beheshti University (Tehran, Iran) and a commercial greenhouse (Pakdasht, Tehran, Iran) during 2022–2023. Anthurium cut flowers (cv. 'Fire Glow') with red spathe were harvested early in the morning at the commercial maturity stage when 50% of flowers on the spadix had been opened and then, were placed in tubes containing distilled water and transported to the laboratory. After recutting to a uniform height of 45 cm, cut…

CI index and vase-life

Obtained results demonstrated that CI index increased with increasing storage duration and the highest CI index was recorded on 21 d. All AsA treatments led to decreasing CI index comparing to control. In all storage durations, the highest and lowest CI index were related to pulse treatment at 2 mM concentration and control, respectively. In sprayed flowers, CI index decreased with increasing AsA concentration from 1 to 4 mM, so that spraying at 4 mM concentration led to lower CI index than 1…

Discussion

Anthurium is native to tropical regions and its storage at temperatures of lower than 10 ºC causes CI and vase-life shortening (Soleimani Aghdam et al., 2016a). The positive effects of AsA post-harvest treatments on maintainability of anthurium cut flowers during cold storage were observed in this study which is in line with those reported by Jin et al. (2006) and Abri et al. (2013) on rose cut flowers, Sheikh et al. (2014) on lisianthus cut flowers and Khattab et al. (2017) on gladiolus cut…

Conclusions

In the current study, post-harvest exogenous application of AsA led to an increase in endogenous content of SA and AsA, and enhanced antioxidant capacity of anthurium cut flowers during storage at 4 ºC. This treatment significantly reduced CI index and extended the cut flowers vase-life. Also, results of the present study demonstrated that pulse treatment could be more effective than spraying treatment in terms of alleviating the low temperature negative effects. Therefore, AsA pulse treatment…

CRediT authorship contribution statement

Meisam Mohammadi: Conceptualization, Field-test, Investigation, Data collection, Formal analysis, Writing, Project administration. **Ghasem Eghlima:** Conceptualization, Field-test, Investigation, Writing – review & editing. **Mohamad-Ebrahim Ranjbar:** Conceptualization, Methodology, Writing….

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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