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THE IMPACT OF PRE-HARVEST TREATMENT WITH GAMMA--AMINOBUTYRIC ACID (GABA) AND SALICYLIC ACID ON VASE LIFE AND POST-HARVEST TRAITS OF TUBEROSE CUT FLOWERS

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ABSTRACT

Tuberose (*Polianthes tuberosa* L.) is an ornamental bulbous plant and a famous cut flower in tropical and subtropical regions. Post-harvest senescence of the cut flowers is the main factor limiting the marketability of most of these species including tuberose. From the perspective of metabolic changes, senescence happens as the result of oxidative processes induced by active oxygen species production. Gamma-aminobutyric acid (GABA) and salicylic acid (SA) are compounds with some functions in the post-harvest physiology of some plants. The present study focused on the effect of GABA and SA on vase life and some post-harvest traits of cut tuberose flowers. The plants were sprayed with GABA (5, 10, or 15 mg L^{-1}) and SA (50, 100, or 150 mg L^{-1}) at three stages during growth and before harvest in a greenhouse (30, 45, and 60 days after the planting of the bulbs) and were observed after harvest until senescence. Results showed that GABA and SA positively affected the vase life, water uptake, fresh weight, ion leakage, total dissolved solids, chlorophyll, protein, and catalase, peroxidase, and ascorbate peroxidase enzymatic activity. They postponed senescence. The highest and lowest vase lives were observed in plants treated with 10 mg L^{-1} GABA (11 days) and control (distilled water) (7 days), respectively. It was found that the treatment of tuberose with GABA and SA during growth can improve its post-harvest quality. However, it is recommended to conduct further studies on them.

Key words: ornamental bulbous plants, enzymatic activity, GABA, post-harvest, SA, tuberose

INTRODUCTION

Tuberose (*Polianthes tuberosa* L.) is an ornamental bulbous plant, the cut flowers of which are popular in tropical and subtropical zones. Tuberose is a famous cut flower throughout the world including Iran, where it is widely grown in flower production regions [Jowkar and Salehi 2006]. The genus *Polianthes* belongs to the family *Agavaceae*, is native to Mexico, and contains 12 species [Naz et al. 2012].

Post-harvest senescence of cut flowers is a major factor limiting the marketability of most species, therefore extensive attempts have been made to extend their post-harvest life by the application of various chemical treatments [Bowyer and Wills 2003]. It has been reported that plant hormones are involved in the regulation of flower senescence so that the changes in the level of these compounds act as a regulat-

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ing signal for the senescence and may retard it [Singh et al. 2002]. The process of senescence results from a set of physiological and metabolic changes leading to the death of cells, organs, and/or living organisms. From the perspective of metabolic changes, aging is the consequence of oxidative processes induced by the generation of active oxygen species [Oh et al. 2003]. Aminobutyric acid is one of the compounds that are involved in the post-harvest physiology of some plants. This acid can be extensively found in nature among microorganisms, plants, and animals. It was first identified in potato [Chew and Seymour 2013] and has been also observed in some plant resources including vegetables, fruits, and grains – e.g. in spinach, broccoli, tomato, potato, grape, barley, and corn – in very slight quantities [Oh et al. 2003].

It was reported that pre-harvest and post-harvest treatment of anthurium cut flowers with aminobutyric acid extended their vase life. On the other hand, the decreased activity of phospholipase D increased the ratio of unsaturated to saturated fatty acids, reduced the accumulation of hydrogen peroxidase and active oxygen species, and alleviated damage of chilling by protecting the membrane integrity [Soleimani Aghdam et al. 2016]. Unlike atmospheric oxygen, active oxygen species have a very high tendency to react with all biological macro-molecules of the cells so that they react with proteins, lipids, carbohydrates, and nucleic acids of the cells, and thereby degrade proteins, deactivate enzymes, damage membranes, and decompose polysaccharides [Mittler et al. 2004]. The application of GABA increased the post-harvest life of bananas and peaches [Yang et al. 2011, Wang et al. 2014].

Another compound that is used to enhance the post-harvest quality of flowers and fruits is salicylic acid. Salicylic acid (SA), or ortho-hydroxybenzoic acid ($C_7H_6O_3$), is a simple phenolic compound with multiple properties. It is a very prevailing compound across the plant kingdom and is today known as a plant hormone. SA is involved in the regulation of many growth and development processes of the plants [Raskin 1992]. It hinders senescence by interfering in ethylene biosynthesis and, thereby, extends the vase life of the cut flowers [Serek 1992]. De Capdeville et al. [2003] reported that SA treatment of roses extended their post-harvest life. According to Vahdati Mashhadian et al. [2012], SA at the rates of 100, 200, and 300 mg l^{-1} increased the flower life and some qualitative traits of cut chrysanthemum flowers.

The present study aimed to explore the impact of the foliar application of salicylic acid and gamma-aminobutyric acid on the post-harvest life and some qualitative traits of cut tuberose flowers.

MATERIAL AND METHODS

The study was carried out on tuberose (*Polianthes tuberosa* L.) in the research greenhouse of Gorgan University of Agricultural Sciences and Natural Resources in 2016. Uniform tuberose bulbs with the diameter of 2 cm and approximate fresh weight of 45 g were procured from a tuberose production center in Dezful, Iran. Prior to planting, they were immersed in Mancozeb Fungicide (2 : 1000) for 20 minutes [Singh 2006]. The growing substrate was composed of manure, sand, leaf mold, and garden soil in equal ratios. Two bulbs were planted in each pot with the mouth diameter of 30 cm. The treatments included the foliar application of salicylic acid (SA) and gamma-aminobutyric acid (GABA), both at three levels of 50, 100, or 150 mg L^{-1}. They were applied at three stages (30, 45, and 60 days after planting of the bulbs). The control contained distilled water.

The recorded traits included vase life, stem length, ionic leakage, fresh weight of shoot, water uptake, leaf protein concentration, total dissolved solids, catalase activity, peroxidase activity, ascorbate peroxidase activity, chlorophyll *a* and *b*, and total chlorophyll content.

Vase life was assessed by Reid's [1996] procedure considering the color change in flowers, floret shedding, flowering opening rate, and stem end viscosity.

Flower fresh weight was measured with a digital scale using the following equation [Vahdati Mashhadian et al. 2012]:

$$\text{relative fresh weight} = \frac{w_t}{w_t = 0} \times 100$$

w_t = stem fresh weight in the same dayand days 3, 6, ...w_t = 0 = weight of the stem in day zero. The solution uptake was determined by a digital scale. Reezi's et al. [2009] procedure was applied for ion leakage measurement. 0.5 g petal was cut in 1 × 1 cm^2 pieces from each sample. Then, they were rinsed with distilled wa-

ter and were placed in falcon containers containing 25 ml twice-distilled water. Then, they were placed in a shaker at 150 rpm for 30 minutes at 25°C, and their EC petals was read (EC_1). The containers were, then, placed in a bain-marie at 95°C for 15 minutes and their EC_2 was read after cooling down. The ion leakage percentage was measured by the following equation:

$$\text{ion leak percentage} = \frac{EC_1}{EC_2} \times 100$$

EC_1 = petal electrical conductivity (primary). EC_2 = petal electrical conductivity (second).

To determine the protein content, we first prepared Bradford solution and then, 2.5 ml of this solution was mixed with 50 µl enzyme extract, it was placed in darkness for 15 minutes, and it was finally read at 595 nm [Bradford 1976].

To measure total soluble solids of petals, 0.5 g of petals was separated and ground in a mortar. Then, it was extracted and its degrees Brix were determined with a refractometer.

Catalase activity was determined by specifying the reduction of H_2O_2 at 240 nm for one minute. The reaction solution contained 100 mM potassium phosphate buffer (pH = 7), 15 mM H_2O_2, and 50 µl enzyme extract adjusted to the volume of 3 ml. Enzyme activity was estimated by the coefficient of extinction assumed to be 39.4 cm^{-1} mM^{-1} and was expressed for one unit (µM hydrogen peroxide consumed in 1 minute) per mg protein [Aebi 1984].

To measure peroxidase activity, 45 mM guaiacol buffer and 225 mM hydrogen peroxide buffer were applied. At a low temperature, 475 µl of each buffer was mixed with 50 µl of the extract, and it was read at 470 nm with a spectrophotometer (PG Instrument + T80) [In et al. 2007]. Enzymatic activity was calculated by using the Beer-Lambert law and the coefficient of extinction of the guaiacol catalysis product of the peroxidase. It was expressed in µM g^{-1} FW min^{-1}.

Ascorbate peroxidase activity was measured by Nakano and Asada's [1981] method in which the reaction mixture contained 50 mg L^{-1} potassium phosphate buffer (pH = 7), 0.5 mM ascorbate, 0.1 mM hydrogen peroxide, and 150 µl enzyme extract. The petals were used to prepare the enzyme extract. 0.5 g of fresh weight of the petal was weighed and transferred to cold mist and washed with 3 ml of buffer. The obtained homogenization was then performed at a rate of 5000 rpm for centrifugation for 20 minutes. The supernatant solution was used as raw extract to measure antioxidant enzymes activity. Ascorbate activity was measured on the basis of the oxidation of ascorbic acid and the loss of the absorption at 290 nm over 2 minutes. Enzyme unit was calculated by the coefficient of extinction assumed to be 2.8 cm^{-1} mM^{-1}. An enzyme unit is an amount of enzyme that oxidizes 1 mM ascorbate acid in 1 minute.

Chlorophyll content was determined by Barns' (1992) method. We first weighed 0.150 g of fresh leaf from each replication and mixed it with 1.5 ml dimethyl sulfoxide (DMSO). It was oven-dried at 80°C for three hours. Then, 250 µl was separated and was added again with 2 ml of DMSO. Pure DMSO was used as the blank. The samples were read at 645 and 663 nm with a spectrophotometer to determine chlorophyll *a* and *b* and total chlorophyll using the following equation:

$$\textit{Chlo}\ a\ (mg/g\ f.w.) = 12.7(A_{663}) - 2.69(A_{645}) * V/1000 * W$$

$$\textit{Chlo}\ b\ (mg/g\ f.w.) = 22.9(A_{645}) - 4.68(A_{663}) * V/1000 * W$$

$$\textit{Chlo}\ total\ (mg/g\ f.w) = 20.2(A_{645}) + 8.02(A_{663}) * V/1000 * W$$

A = wavelength, V = final solution volume, W = sample weight.

The study was based on a Randomized Complete Block Design with two treatments (in different levels) and three replications Data were analyzed with the SAS software package and the means were compared by Fisher LSD test in the level of 5%.

RESULTS AND DISCUSSION

The analysis of variance showed that the treatments and post-harvest time influenced the measured traits of cut tuberose flowers significantly at the 5 and 1% probability levels (Tabs 1, 2, 3).

Table 1. Analysis of variance effects of GABA and SA treatments on vase life of tuberose cut flowers

S.O.V	Vase life
Treatment	6.42*
Error	2.04
Cv (%)	16.24

* a significant difference in the level of 5%

Table 2. Analysis of variance of the effect of treatment dose and application stage on physiological characteristics of tuberose cut flowers

S.O.V	df	Ion leakage of petals	Fresh weight of shoot	Water uptake	Lear protein	Total soluble solids of petals
Treatment	6	1024.14**	1121.92**	80.02**	0.10**	1.02**
Time	2	45714.92**	993.99**	677.77**	0.18**	6.87**
Treatment × Time	12	1054.9**	70.22**	214.35**	0.001ns	0.51
Error	42	414.05	5.01	5.15	0.002	0.11
Cv (%)		3.75	2.93	11.006	19.91	7.81

*, **, ns: respectively, a significant difference in the level of 5% and 1%, and no significant difference

Table 3. Analysis of variance of the effect of treatment dose and application stage on biochemical characteristics of tuberose cut flowers

S.O.V	df	Catalase	Peroxidase	Ascorbate peroxidase activities	Chlorophyll *a* of leaf	Chlorophyll *b* of leaf	Total chlorophyll of leaf
Treatment	6	0.75**	0.61**	5.90**	0.001**	0.048**	0.042**
Time	2	5.62**	0.25**	9.42**	0.018**	0.063**	0.15**
Treatment × Time	12	0.21**	0.19**	0.36**	0.001**	0.014**	0.023**
Error	42	0.01	0.002	0.04	0.00009	0.002	0.002
Cv (%)		13.15	8.71	7.32	10.51	19.65	14.82

*, **: respectively, a significant difference in the level of 5% and 1%

Vase life

According to means comparison, the longest vase life of 11 days was related to plants treated with 10 mg L^{-1} and 15 mg L^{-1} GABA followed by 10 days observed in plants treated with 150 mg L^{-1} SA. Untreated control showed the shortest vase life (Fig. 1).

Fan et al. [2008] stated that SA is a plant phenol that hinders the activity of ACC (aminocyclopropane-1-carboxylic acid) oxidase as the ethylene precursor and thereby reduces ethylene production and extends the vase life of cut gerbera flowers. The desirable impact of SA on vase life of the flowers may be related to its role in improving their systemic resistance to pathogens that are a major factor in post-harvest senescence. Pre-harvest application of SA increased the quality and vase life of cut rose flowers [Hashemabadi and Zarchini 2010]. Soleimani Aghdam et al. [2016] reported that cut anthurium flowers pre-harvest treatment with GABA increased their vase life as it occurred in our study as well. They related this effect

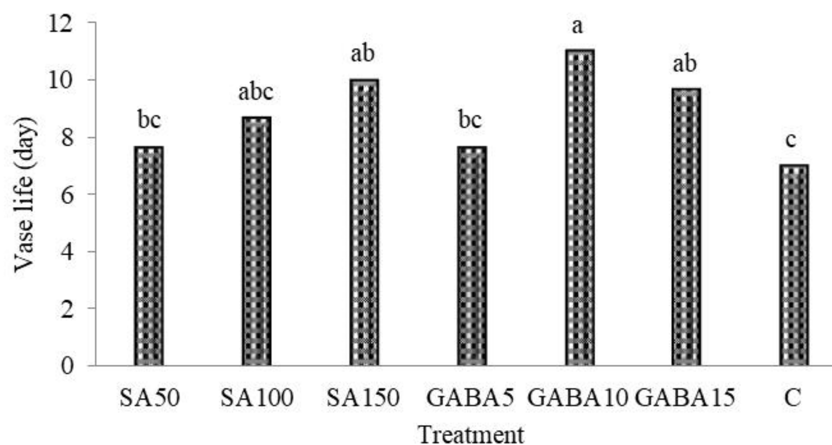

Fig. 1. Effect of salicylic acid (SA) and GABA on the vase life of tuberose cut flowers

to the role of GABA in reducing the peroxidation of lipids, which results in preserving cell integrity.

Ion leakage

Results for ion leakage revealed the highest and lowest leakages in the untreated control and plants treated with 5 mg L^{-1} and 15 mg L^{-1} GABA, respectively. Also, SA at all rates caused significant differences in this trait as compared to control so that it reduced ion leakage (Tab. 4). The trend of ion leakage variation over time was therefore the lowest leakage was recorded on the first day of postharvest of flowers and, then, it showed an ascending trend on the next days (Tab. 5).

It has been revealed that cell stability index, which expresses the ion leakage of the tissues, differs slightly among different cut flowers at early harvest time, but as the longevity increases, remarkable differences appear among them [Ezhilmanthi et al. 2007, Singh et al. 2008]. Senaratna et al. [2002] reported that foliar application of SA reduced ion leakage in tomatoes and beans. The increase in SA rate decreases ion leakage because SA enhances dissolved carbohydrate contents via decomposing the insoluble sugars. Similar findings were reported by Fan et al. [2008] for gerbera, in which SA helped cell wall to keep its integrity and caused longer longevity of the flowers. Our finding about the effective role of GABA in reducing ion leakage is in agreement with Soleimani Soleimani Aghdam et al. [2016]. They observed that the treatment of anthurium with GABA was related to the lower activity of phospholipase and lipoxygenase. This was along with the higher ratio of unsaturated to saturated fatty acids and contributed to the preservation of cell integrity under chilling stress. This can be partially attributed to the role of this compound in retarding the loss of ion leakage since the ion leakage increases in plants during their storage perhaps because of the increased activity of lipoxygenase enzyme [Sirikesorn et al. 2015]. Aghdam et al. [2015] also reported the impact of GABA on reducing the ion leakage in anthurium plants, which supports our findings.

Flower fresh weight

As means comparison revealed, the highest and lowest fresh weights were related to plants treated with 15 mg L^{-1} GABA and control, respectively. Also, all SA concentrations showed significant differences with control (Tab. 4). The highest fresh weight was recorded at the second measurement stages (day 4) and then, it started to be lost (Tab. 5).

It was found that flower fresh weight started to decrease after some days in storage. But, the treatments postponed the loss of post-harvest flower weight. Fresh weight is a crucial parameter in the wilting of the flowers. A major reason for the decrease in fresh weight is the blockage of stem vessels due to the growth of microorganisms. Flower aging is accompanied by water loss, thus imbalance is developed in water uptake and transpiration of the cut flowers over senescence, cell turgor is lost, and flow-

Table 4. Effect of salicylic acid and GABA on post-harvest characteristics of tuberose cut flowers

Treatment	Ion leakage	Fresh weight	Water uptake	Leaf protein	Total soluble solids
SA50	90.77b	77.51b	24.44a	0.27b	4.31b
SA100	81.56cd	77.21b	23.33ab	0.33a	4.68a
SA150	80.04d	76.22b	21.66b	0.13c	4.84a
GABA5	91.66ab	67.27cd	17.77c	0.14c	4.22b
GABA10	83.10c	69.34c	17.77c	0.25b	4.34b
GABA15	62.87e	99.37a	22.22b	0.37a	3.82c
C	94.54a	67.17d	17.22c	0.1d	4.17b

Means marked with similar letters in each column are not significantly different at 5% and 1% level of probability using LSD test

Table 5. Trend of post-harvest physiological characteristics of tuberose cut flowers (pre-treatment with salicylic acid and GABA)

Time of postharvest (day)	Ion leakage	Fresh weight	Solution uptake	Leaf protein	Total soluble solids
1	31.80c	79.004b	22.38b	0.33a	4.71a
4	96.28b	81.54a	25.23a	0.20b	4.62a
7	122.45a	68.56c	14.28c	0.14c	3.68b

Means marked with similar letters in each column are not significantly different at 5% and 1% level of probability using LSD test

ers wilt [Reid 2002]. Hayat and Ahmad [2007] stated that SA could have a desirable impact on stomatal closure and opening. Since water loss *via* stomata at post-harvest phase is a cause of cut flowers wilting [Van Doorn 2012], it can be suspected that SA retarded the loss of fresh weight in cut tuberose flowers by affecting the stomata positively. Mirzaei Mashhoud et al. [2016] found that GABA improved the fresh weight of rose flowers, which is consistent with our findings. We can say that the positive effect of GABA on retarding tuberose fresh weight loss is attributed to the retention of cell structure.

Water uptake

Plants treated with 50 mg L^{-1} SA showed the highest water uptake and control plants showed the lowest one (Tab. 4). Also, the trend of water uptake variations indicated that it was increased up to day 4 of postharvest and then, it started to descend (Tab. 5).

Flower senescence is accompanied by water loss, therefore water uptake and transpiration are unbalanced in cut flowers during senescence, cell turgor is lost, and the flowers start to wilt [Reid 2002]. Therefore we found that SA at different rates and GABA at the rate of 15 mg L^{-1} increased water uptake by the flowers, Ezhilmanthi et al. [2007] reported that 100 mg l^{-1} SA decreased cell membrane permeability, resulting in the postponement of senescence in gladiolus cut flowers. They argued that this was mainly due to the improvement of water relations in these flowers. The treatment of chrysanthemum flowers with 300 mg l^{-1} SA increased their water uptake [Vahdati Mashhadian et al. 2012].

Leaf protein content

According to means comparison, the lowest leaf protein content was obtained from plants treated with 5 mg L^{-1} GABA although it did not differ from that of 100 mg l^{-1} SA significantly. Also, the lowest protein content was related to control (Tab. 4). The variation trend of protein content indicated that the highest protein content was recorded on day 1 and then it decreased (Tab. 5).

Leaf senescence is usually accompanied by the loss of protein content due to the lower rate of the synthesis of new proteins and the decomposition of the already existing proteins [Lay-Yee et al. 1992]. Sood et al. [2006] reported the reduction of protein content during flower aging, which is consistent with our findings. Lerslerwonga et al. [2009] reported that peptidase activity in *Dendrobium* increased before the emergence of senescence symptoms. Therefore, the increased activity of peptidase was related to the loss of water-soluble proteins. SA can be involved in the activation of the genes pertaining to resistance proteins, thereby enhancing protein content [Shah 2003].

Total soluble solids (TSS) content

Means comparison indicated that the treatment of 150 mg L^{-1} SA and control but also SA50 were related to the highest and lowest TSS, respectively. Although GABA increased TSS slightly (Tab. 4), it did not create a significant difference versus control except for GABA15 (Tab. 4). Also, a look at the variation trend of TSS over time shows that the highest TSS was obtained on day 1 and then it followed a descending trend (Tab. 5).

Most cut flowers still have certain levels of soluble sugars in their leaves when they wilt. This reflects the fact that cells store a quantity of sugar even during wilting. In spite of the presence of a high concentration of sugars in vacuoles, cell organelles including mitochondria are likely to be unable to use it. This inability of organelles in the uptake of sugar results in the loss of flower longevity and leaf wilting [Van Doornm 2001]. Since SA inhibits the activity of ACC synthase and the formation of ethylene [Li et al. 1992], it can be said that this compound postpones the decomposition of carbohydrates by reducing the respiration rate.

Catalase, peroxidase, and ascorbate peroxidase activities

According to Table 6, the highest and lowest activities of catalase, peroxidase, and ascorbate peroxidase enzymes were observed in plants treated with 15 mg L^{-1} GABA and control, respectively. SA changed the activity of these enzymes significantly as compared to

Table 6. Effect of salicylic acid and GABA on measured characteristics of tuberose cut flowers

Treatment	CAT	POD	APX	Chlorophyll *a*	Chlorophyll *b*	Total chlorophyll
SA50	0.99b	0.77b	3.01d	0.11a	0.38a	0.48a
SA100	1.13a	0.60d	3.08d	0.097b	0.27b	0.37b
SA150	0.51d	0.35f	3.81b	0.096b	0.25b	0.35b
GABA5	0.52d	0.20g	1.92e	0.076c	0.27b	0.35b
GABA10	0.76c	0.65c	3.32c	0.084c	0.28b	0.36b
GABA15	1.14a	0.97a	4.08a	0.094b	0.25b	0.35b
C	0.52d	0.45e	2.08e	0.098b	0.13c	0.24c

Means marked with similar letters in each column are not significantly different at 5% and 1% level of probability using LSD test

Table 7. Trend of post-harvest physiological characteristics of tuberose cut flowers (pre-treatment with salicylic acid and GABA)

Time	CAT	POD	APX	Chlorophyll *a*	Chlorophyll *b*	Total chlorophyll
1	1.25a	0.68a	3.70a	0.12a	0.31a	0.44a
4	0.90b	0.57b	3.07b	0.09b	0.27b	0.37b
7	0.23c	0.46c	2.36c	0.06	0.20c	0.27c

Means marked with similar letters in each column are not significantly different at 5% and 1% level of probability using LSD test

control. Also, the activity of these enzymes varied over time in a manner that the highest level was recorded on day 1 and then, it had a descending trend (Tab. 7).

Plants are equipped with enzymatic and non-enzymatic antioxidant mechanisms to cope with the oxidative stress induced by active oxygen radicals [Alscher et al. 2002]. The antioxidant enzymes include peroxidase, glutathione reductase, superoxide dismutase, and catalase [Hsu and Kao 2003]. Hossaina et al. [2005] stated that the loss of ascorbate peroxidase enzyme activity plays a key role in cell senescence. Since the senescence of flower petals is associated with continuous and rapid production of free radicals [Kumar et al. 2010], then the increase in the accumulation of free oxygen species induced by senescence may be offset by the increase in antioxidants and free oxygen species scavenging enzymes [Van Doom and Woltering 2008]. Catalase activity has been measured in the petals of different plants including iris and carnation [Bailly et al. 2001, Zhang et al. 2007]. These reports show the decrease in catalase activity with senescence which is consistent with the variation of the trend of this enzyme in our study. GABA increased antioxidant enzymes in anthurium and thereby reduced the peroxidation rate of lipids [Aghdam et al. 2015], which supports our results about the increased activity of antioxidant enzymes in tuberose cut flowers.

Salicylates postpone cell senescence in flower by boosting the activities of antioxidant enzymes and enhancing antioxidant system [Armitage and Laushman 2003]. SA priming enhanced the activity of the enzymatic antioxidant defense system, such as ascorbate peroxidase, catalase, and peroxidase enzymes. Oxidative stress is counteracted by the increased activity of ascorbate peroxidase, which activates ascorbate-glutathione cycle and hydrogen peroxide scavengers, and then by the increased activity of catalase and other peroxidases [Agarwal and Pandey 2004]. Therefore, in the present study, SA application possibly activated antioxidant defense system and thereby improved plant resistance and its post-harvest traits. Wang et al. [2009] reported that SA had an improving impact on ascorbate peroxidase enzyme activity in corn.

Chlorophyll *a* and *b* and total chlorophyll

According to means comparison, the highest and lowest chlorophyll *a* and *b* and total chlorophyll contents were related to plants treated with 50 mg L^{-1} SA and control, respectively (Tab. 6). Also, their variation trend over time shows that the highest level was observed on day 1 and then, it had a descending trend (Tab. 7).

Chlorophyll plays an essential role in plants in terms of light energy interception and application in photosynthesis. SA is a key regulator that influences the structure of chloroplast and chlorophyll [Uzunova and Popova 2000, Fariduddin et al. 2003]. Singh and Usha [2003] reported that SA application increased chlorophyll content of wheat. Since the present study revealed that the loss of leaf chlorophyll was retarded in SA-treated plants, it may be concluded that the effect of this compound arises from the inhibition of ethylene production mechanism [Li et al. 1992] and, consequently, the postponement of flower senescence. The treatment of black pepper seeds with GABA improved chlorophyll *a* and *b* [Vijayakumari and Puthur 2016], which is in agreement with our findings.

CONCLUSION

It was revealed that the application of SA and GABA during tuberose cut flower growth improves vase life and some post-harvest qualitative traits of this species. These two compounds enhance the antioxidant system of the plant and thereby improve the activity of antioxidant enzymes and postpone the senescence of the flower. Also, the anti-ethylene property of SA has a key role in extending the longevity and improving the quality of tuberoses. According to the results, SA that has been applied in various studies in recent years, and GABA that is a relatively new compound, can be applied during the growth stages of tuberoses. Nonetheless, further studies are recommended on how they, especially GABA, work.

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