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Effect of some chemical and natural preservative solutions on vase life, water relations and some chemical composition of *Dianthus caryophyllus* L. cut flowers

A.M.Z. Sarhan [1], **A.A.M. Heikal** [1], **F.M. Saadawy** [2], **T.M. Noor El-Deen** [2], **K.M. Abd Elkareem** [2 (*)]

[1] *Ornamental Horticulture Department, Faculty of Agriculture, Cairo University, Cairo, Egypt.*

[2] *Ornamental Plants and Landscape Gardening Research Department, Horticultural Research Institute, Agricultural Research Center, Giza, Egypt.*

(*) **Corresponding author:**
koki_assem@yahoo.com

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Abstract: To investigate the effect of some pulsing and holding solutions on the quality of carnation cv. Turbo cut flowers, a laboratory experiment was conducted in the Agricultural Research Center and Cairo University, Egypt during 2020 and 2021 seasons. In this regard distilled water, silver thiosulfate (STS) at 0.4 ppm + sucrose 10% (PS1) and $AgNO_3$ at 10.0 ppm + sucrose 10% (PS2) were employed as a pulsing solution for 15 min while distilled water, sucrose 4% (HS1), boric acid (BoA) at 200 ppm + sucrose 4% (HS2), 8-hydroxyquinoline sulfate (8-HQS) at 300 ppm + sucrose 4% (HS3), Amino-oxyacetic acid (AOA) at 250 ppm + sucrose 4% (HS4), 8-HQS + AOA + sucrose 4% (HS5), BoA + 8-HQS + sucrose 4% (HS6), BoA + AOA + sucrose 4% (HS7), BoA + 8-HQS + AOA + sucrose 4% (HS8), rosemary extract at 25% + sucrose 2% (HS9) and thyme extract at 25% + sucrose 2% (HS10) were used as holding solutions. Regarding pulsing solutions, PS2 and PS1 exhibited a positive effect on all studied traits, while the mastery was to HS8 concerning the effect of holding solutions. Pulsing cut carnations in a solution containing PS2 followed by holding in HS8 resulted in the highest values in terms of vase life, water balance, chlorophyll a, carotenoids and total sugars, while the highest water uptake and loss and chlorophyll b were obtained by pulsing in PS1 followed by holding in HS8. It is recommended to pulse carnation cv. Turbo cut flowers in $AgNO_3$ at 10.0 ppm + sucrose 10% solution for 15 min followed by holding in BoA + 8-HQS + AOA + sucrose 4% for getting the longest vase life, enhancing water uptake and maintaining water balance. Additionally, this preservative solution effectively reduces chlorophyll degradation and preserves the content of carbohydrates throughout the postharvest period.

1. Introduction

Carnation (*Dianthus caryophyllus* L.; fam. Caryophyllaceae) is native to Southern Europe and the Mediterranean region and is a half-hardy perennial flowering plant with a wide range of colours. Each stem of the carnation forms a terminal flower; hence inflorescence is generally a terminal cyme. The flowering shoots can be single or multiple (stem sprays) (Ponnuswami and Sowmeya, 2015). Moreover, the exceptional keeping qualities of carnations make them an excellent choice for cut flowers. They possess remarkable longevity, the ability to withstand long-distance transportation, and an exceptional capacity to rehydrate even after prolonged shipping (Panwar *et al*., 2022).

There is a wide range of techniques applied to extend flower preservation, including the use of flower preservatives, inhibitors of ethylene action, growth regulators, calcium and the control of temperature and flower dehydration (Finger and Barbosa, 2006). Pulsing solutions are used basically to provide sugars (sucrose or glucose at 2-20%) and silver compounds (STS) (Armitage and Laushman, 2003). Pulsing solutions are used on freshly harvested flowers that are in a bud stage where a short period (or pulse) in a high-sugar solution will extend the vase life or open buds. Sugar is the main ingredient while STS is used to reduce ethylene sensitivity (Jones, 2001). To promote water uptake, the cut flower's stems are placed in a holding solution which contains an acidifier for hydration, a biocide of bacterial control and an energy/food source, which is typically sugar. The flowers usually stay in these solutions for one to several days as they are transported to local distributors and retailers and are used for retail displays (Dole and Faust, 2021).

A lot of chemicals are used in formulations of pulsing or/and holding solutions e.g. STS, $AgNO_3$, 8-HQS, AOA and boric acid. Ebrahimzadeh *et al.* (2008) concluded that STS is used to inhibit harmful effects of ethylene and prolong vase life in many ornamentals including carnation, $AgNO_3$ inhibits ethylene synthesis and action and is used as an antimicrobial agent, 8-HQS is an antimicrobial additive in preservatives and is ethylene synthesis inhibitor, AOA inhibits the biosynthesis of ethylene, and boric acid used as anti-ethylene synthesis. Various authors have demonstrated the beneficial effects of the aforementioned chemicals, integrated either individually or in combinations into preservative solutions, on carnation cut flowers cvs. Dolce Vita, Amstel, Monte Lisa, Aliceo, and Paola (Wawrzynczak and Goszczynska, 2003), cvs. Kristina, Aleda, Master, and Vienna (Krishnappa and Reddy, 2004), cvs. Nelson, Dream, and Delphi (Lopez *et al.*, 2008), cv. Optima (Karimi *et al*., 2012), cv. Charmant (Darwish *et al*., 2014), cv. Felice (Madhuri *et al*., 2016), and cv. Mirella (Adam and Eldeeb, 2021).

Certain natural materials e.g. plant extracts and essential oils are used instead of chemicals in cut flowers' preservative solutions due to the harmful effects of such chemicals (particularly those based on silver compounds) on human health. A lot of studies were carried out to investigate the effect of these natural materials. In this regard, Hashemabadi *et al.* (2021) on *Dianthus caryophyllus* L. cv. Yellow Candy stated that both vase life and solution uptake were increased by using dill essential oil in the solution compared to distilled water. Numerous studies have provided evidence of the impact of employing natural substances in preserving solutions for carnation cut flowers. For example, investigations have been conducted on the utilization of dill, clove, and coriander oils on cvs. Farida and Madam Collate (Shanan *et al*., 2010); extracts of lupin and clove and juice of the lemon on cv. Domingo (El-Ashwah, 2011); essential oils of dill, geranium and caraway on cv. Yellow Candy (Rad, 2018) and clove essential oil on cv. Cinderella (Eldeeb and Adam, 2021). Such materials were used in these reported studies either individually or in combination with other post-harvest chemicals.

Therefore, the present study was carried out to investigate the effect of different pulsing (mainly STS, $AgNO_3$ or distilled water) and holding (boric acid, 8-HQS, AOA, rosemary and thyme water extracts) solutions on vase life, water relations, pigments content and total sugars of carnation cut flowers with the possibility to get the longest vase live with the best quality.

2. Materials and Methods

A laboratory experiment was carried out in the Post-harvest Lab., Ornamental Plants and Landscape Gardening Res. Dept., Horticulture Res. Inst., Agricultural Research Center, Giza, Egypt and Ornamental Horticulture Dept., Faculty of Agriculture, Cairo University, Egypt during 2020 and 2021 seasons with the aim to study the effect of some pulsing and holding solutions (containing some natural extracts) on the postharvest quality of carnation cut flowers.

Plant materials

Fresh cut flowers of carnation (*Dianthus caryophyllus* L.) cv. Turbo, at the paintbrush stage with red color were obtained from a local commercial greenhouse farm in Giza, Egypt, in the first week of January each season. Flowers' stem lengths were adjusted to 60 cm with 3.0-3.5 cm flower diameter, while fresh weight ranged from 18 to 20 g. Immediately, after transferring to the laboratory under dry conditions, about 5 cm of stem bases were recut under water and 4 pairs of leaves were left on each stem and then rapidly precooled by placing them in cold water for three hours.

Experiment treatments

Pulsing solutions

These precooled cut flowers were distributed in 500 ml jars (3 flowers/jar) and then equally divided into three groups, each one containing 300 ml from one of the following applied pulsing solutions:

1. Distilled water
2. STS at 0.4 ppm + sucrose at 10% (PS1)
3. $AgNO_3$ at 10.0 ppm + sucrose at 10% (PS2)

STS (silver thiosulfate; $1AgNO_3.4Na_2S_2O_3 \cdot 5H_2O$) solution was prepared according to Gorin *et al*. (1985). In this regard, both $AgNO_3$ (0.079 g) and $Na_2S_2O_3 \cdot 5H_2O$ (0.462) were dissolved separately in 500 ml deionized water, then $AgNO_3$ solution was poured into $Na_2S_2O_3 \cdot 5H_2O$ solution with continuous stirring. While the $AgNO_3$ solution was prepared by dissolving 0.01 g of $AgNO_3$ in deionized distilled water to prepare a 10-ppm concentration.

Holding solutions

Each group of the pulsed cut flowers were divided into 11 subgroups (3 flowers/500 ml jar containing 300 ml of different holding solutions) and kept under lab conditions (light intensity at 1000 lux supplied by fluorescent lamps, the average temperature at 18-20°C and relative humidity at 50-55%) as follows:

1. Control (distilled water)
2. Sucrose at 4% (HS1)
3. Boric acid at 200 ppm (BoA) + sucrose at 4% (HS2)
4. 8-hydroxyquinoline sulfate at 300 ppm (8-HQS) + sucrose at 4% (HS3)
5. Amino-oxyacetic acid at 250 ppm (AOA) + sucrose at 4% (HS4)
6. 8-HQS + AOA + sucrose at 4% (HS5)
7. BoA + 8-HQS + sucrose at 4% (HS6)
8. BoA + AOA + sucrose at 4% (HS7)
9. BoA + 8-HQS + AOA + sucrose at 4% (HS8)
10. Rosemary extract at 25% (RE) + sucrose at 2% (HS9)
11. Thyme extract at 25% (TE) + sucrose at 2% (HS10)

Extracts preparation

Both thyme (*Thymus vulgaris* L.) and rosemary (*Rosmarinus officinalis* L.) extracts were prepared by water extraction. In this concern, 250 g of the dry herb was extracted in 250 ml of distilled water with boiling at 100°C and stirring for 30 minutes. After that, the solution was filtered using filter paper, and the remaining solution was completed to 1000 ml with distilled water. Afterwards, 250 ml of each solution was poured into 1000 ml of distilled water to get a 25% concentration.

Experiment design

This experiment was laid out as a complete randomized design (CRD) in a factorial experiment. Factor (A) was represented by 3 levels of pulsing solutions, while factor (B) was represented by 11 levels of holding solutions. Thus, a total of 33 treatments were utilized. Each treatment consisted of 3 replicates, with each replicate containing 3 jars. Within each jar, there were 3 flowers, resulting in a total of 27 flowers per treatment.

Data collection

Vase life

Vase life was determined as the number of days to the beginning of flowers wilting.

Water relations

The total water uptake (g/flower) was calculated by subtracting the weight of water at the end of the experiment from the initial weight.

The total water loss (g/flower) was determined by measuring the difference between the weight of jars with spikes and solution at the beginning of the experiment and the weight of jars with spikes and solution at the end of the experiment.

The total water balance (g/flower) was obtained by subtracting the total water loss from the total water uptake.

Determination of pigments and sugars

At the end of flower longevity, pigment and sugar contents were measured on the attached leaves.

Contents of chlorophylls a, b and carotenoids were determined colourimetrically in fresh leaves according to the method described by Wellburn and Lichtenthaler (1984).

Total sugars in the dry leaves were determined colourimetrically according to Dubois *et al.* (1956).

Statistical analysis

The obtained data were statistically analyzed as a factorial experiment using MSTAT Computer Program (MSTAT Development Team, 1989). Duncan's multiple range test (Duncan, 1955) was used to compare the means between various treatments.

3. Results and Discussion

Vase life

The data reported in Table 1 clearly show that PS2 significantly increased the vase life of carnation cut flowers to 18.4 and 18.7 days in the first and second seasons, respectively. Conversely, pulsing the cut flowers in distilled water solution recorded only 16.3 and 16.5 days in both seasons, respectively.

Preserved carnation cut flowers in different holding solutions showed a significant influence on vase life (days) as presented in Table 1. The highest number of days was recorded by holding in HS8 (24.3 and 24.6 days) in the first and second seasons, respectively. The lowest values were obtained by holding the cut flowers in HS9 (12.6 and 12.9 days), HS10 (12.7 and 13.0 days) and distilled water (12.8 and 12.6 days) in both seasons, respectively.

Comparing to the control treatment (DW), it was evident that all combined treatments involving both pulsing and holding solutions led to a substantial improvement in the vase life of cut carnation flowers. The key technique employed to achieve this outcome involved pulsing the flowers in a PS2, along with

Table 1 - Effect of pulsing and holding solutions and their interaction on vase life (days) of *Dianthus caryophyllus* cv. Turbo cut flowers during 2020 and 2021 seasons

Holding solutions (B)	Pulsing solutions (A)			
	PS1	PS2	DW	Mean (B)
		First season (2020)		
Control (DW)	13.67 o-q	14.18 op	10.67 t	12.84 f
HS1	15.69 l-n	15.98 lm	14.69 no	15.45 e
HS2	18.04 ij	18.02 ij	16.71 kl	17.59 d
HS3	21.44 de	23.11 bc	17.73 jk	20.76 b
HS4	19.09 hi	22.13 c-e	16.38 lm	19.20 c
HS5	17.60 jk	18.00 ij	15.60 mn	17.07 d
HS6	21.87 de	21.24 ef	20.33 fg	21.15 b
HS7	20.11 gh	19.36 gh	19.42 gh	19.63 c
HS8	23.98 b	26.67 a	22.40 cd	24.35 a
HS9	12.67 qr	13.29 pq	11.84 rs	12.60 f
HS10	13.09 pq	11.04 st	14.00 op	12.71 f
Mean (A)	17.93 b	18.46 a	16.34 c	
		Second season (2021)		
Control (DW)	13.00 p-r	14.23 n-p	10.83 s	12.69 f
HS1	15.45 l-n	16.00 k-m	14.90 m-o	15.45 e
HS2	18.23 g-i	18.10 g-i	17.13 i-k	17.82 d
HS3	21.68 de	23.63 bc	17.80 h-j	21.04 b
HS4	19.51 fg	22.20 c-e	16.50 j-l	19.40 c
HS5	17.93 h-j	18.87 gh	16.33 k-m	17.71 d
HS6	22.30 cd	21.50 de	20.80 ef	21.53 b
HS7	20.80 ef	19.53 fg	19.50 fg	19.94 c
HS8	24.57 b	27.00 a	22.23 c-e	24.60 a
HS9	13.43 p	13.60 op	11.83 q-s	12.96 f
HS10	13.23 pq	11.63 rs	14.33 n-p	13.07 f
Mean (A)	18.19 b	18.75 a	16.56 c	

PS1= STS at 0.4 ppm + sucrose 10%, PS2= AgNO3 at 10.0 ppm + sucrose 10%, HS10 sucrose 4%, HS2= boric acid at 200 ppm + sucrose 4%, HS3= 8-HQS at 300 ppm + sucrose 4%, HS4= AOA at 250 ppm + sucrose 4%, HS5= 8-HQS + AOA + sucrose 4%, HS6= boric acid + 8-HQS + sucrose 4%, HS70= boric acid + AOA + sucrose 4%, HS8= boric acid + 8-HQS + AOA + sucrose 4%, HS9= rosemary extract at 25% + sucrose 2%, HS10= thyme extract at 25% + sucrose 2%.

holding them in HS8. This combination resulted in vase lives of 26.6 and 27.0 days in both seasons, respectively.

The lowest number of days of vase life in both seasons was recorded by pulsing and holding in distilled water only (10.6 and 10.8 days), pulsing in PS2 + holding in HS10 solution (11.0 and 11.6 days) and pulsing in distilled water and holding in HS9 solutions (11.8 and 11.8 days), respectively.

The aforementioned findings were consistent with the results obtained in previous studies on carnation e.g. Serrano *et al.* (2001), Lopez *et al.* (2008), Hashemabadi (2014), Liu *et al.* (2018) and Gocan *et al.* (2021). Similar outcomes were observed on roses cut flowers (Elgimabi, 2014; Kumar *et al.*, 2017), gerbera (Bhanushree and Rao, 2015; Jafarpour *et al.*, 2015), hydrangeas (Kazaz *et al.*, 2020; Suntipabvivattana *et al.*, 2020), Cymbidium (Usha *et al.*, 2014). Kabari and Soleimandarabi (2019) focused on Alstroemeria cut flowers, while Ichimura *et al.* (2009) examined cut *Eustoma*, *Delphinium*, and snapdragon flowers.

In this regard, Darwish *et al.* (2014) reported that using a solution of 300 ppm 8-HQS + 40 g/l sucrose and 0.4 mM STS + 50 g/l sucrose significantly increased vase life of carnation cut flowers cv. Felice. Also, Badawy *et al.* (2016) revealed that $AgNO_3$ showed the longest vase life of *Chrysanthemum* cut flowers cv. Royal Accent.

Water relations

Water uptake

Data reported in Table 2 show that PS1 solution significantly enhanced water uptake of carnation cut flowers resulting in the highest values in both seasons, (48.2 and 49.9 g/flower in 2020 and 2021,

Table 2 - Effect of pulsing and holding solutions and their interaction on water uptake (g/flower) of *Dianthus caryophyllus* cv. Turbo cut flowers during 2020 and 2021 seasons

Holding solutions (B)	Pulsing solutions (A)			
	PS1	PS2	DW	Mean (B)
First season (2020)				
Control (DW)	36.52 mn	36.55 mn	32.06 p	35.04 g
HS1	47.74 h-j	36.20 mn	34.01 op	39.32 f
HS2	57.35 d	50.23 fg	46.81 ij	51.46 c
HS3	52.18 ef	48.95 gh	48.85 g-i	49.99 d
HS4	50.57 fg	40.68 l	40.96 kl	44.07 e
HS5	59.70 c	57.10 d	54.11 e	56.97 b
HS6	56.49 d	46.68 j	46.54 j	49.91 d
HS7	46.71 j	42.77 k	45.90 j	45.12 e
HS8	67.61 a	65.47 b	60.15 c	64.41 a
HS9	29.31 q	37.80 m	37.53 m	34.88 g
HS10	26.79 r	34.56 no	29.95 q	30.43 h
Mean (A)	48.27 a	45.18 b	43.35 c	
Second season (2021)				
Control (DW)	38.42 mn	38.46 mn	34.10 p	36.99 g
HS1	49.42 h-j	38.23 mn	36.11 o	41.25 f
HS2	58.75 d	51.85 fg	48.53 ij	53.04 c
HS3	53.74 ef	50.60 gh	50.50 g-i	51.61 d
HS4	52.17 fg	42.58 l	42.85 kl	45.87 e
HS5	61.03 c	58.51 d	55.61 e	58.39 b
HS6	57.92 d	48.41 j	48.27 j	51.53 d
HS7	48.43 j	44.60 k	47.64 j	46.89 e
HS8	68.71 a	66.63 b	61.47 c	65.60 a
HS9	31.55 q	39.78 m	39.53 m	36.95 g
HS10	29.11 r	36.64 no	32.17 pq	32.64 h
Mean (A)	49.93 a	46.94 b	45.16 c	

PS1= STS at 0.4 ppm + sucrose 10%, PS2= AgNO3 at 10.0 ppm + sucrose 10%, HS10 sucrose 4%, HS2= boric acid at 200 ppm + sucrose 4%, HS3= 8-HQS at 300 ppm + sucrose 4%, HS4= AOA at 250 ppm + sucrose 4%, HS5= 8-HQS + AOA + sucrose 4%, HS6= boric acid + 8-HQS + sucrose 4%, HS70= boric acid + AOA + sucrose 4%, HS8= boric acid + 8-HQS + AOA + sucrose 4%, HS9= rosemary extract at 25% + sucrose 2%, HS10= thyme extract at 25% + sucrose 2%.

respectively). The lowest significant values were recorded when the cut flowers were pulsed in a distilled water solution. (43.3 and 45.1 g/flower in 2020 and 2021, respectively).

All applied holding solutions positively affect the water uptake of cut carnations as shown in Table 2. The holding solution containing HS8 resulted in the highest water uptake (64.4 and 65.6 days in 2020 and 2021, respectively). On the other hand, holding in solutions containing either rosemary or thyme extracts adversely affected water uptake of carnation cut flowers (34.8 and 36.9 g/flower for rosemary and 30.4 and 32.6 g/flower for thyme extract in 2020 and 2021, respectively). Furthermore, it is noteworthy that when the flowers were held in a distilled water solution alone, it exhibited a similar effect to holding them in a solution containing rosemary extract, with no significant difference observed (35.0 and 36.9 g/flower in the first and second seasons, respectively.

With regard to the interaction between pulsing and holding solutions, it can be observed that pulsing in PS1 solution followed by holding in HS8 recorded the highest significant values in both seasons (67.6 and 68.7 g/flower, respectively in 2020 and 2021). Water uptake of carnation cut flowers was decreased by all applied pulsing solutions when combined with holding solutions containing either rosemary, thyme or only distilled water. The lowest values in this regard were obtained by pulsing in PS1 in addition to holding in HS10 solutions (26.7 and 29.1 g/flower in 2020 and 2021, respectively).

Water loss

As shown in Table 3, the greatest water loss was observed when the flowers were pulsed in PS1 in both seasons. The water loss values recorded were

Table 3 - Effect of pulsing and holding solutions and their interaction on water loss (g/flower) of *Dianthus caryophyllus* cv. Turbo cut flowers during 2020 and 2021 seasons

Holding solutions (B)	Pulsing solutions (A)			
	PS1	PS2	DW	Mean (B)
	First season (2020)			
Control (DW)	38.23 ij	41.25 f-h	37.46 jk	38.98 e
HS1	49.26 d	33.77 l-n	33.21 mn	38.75 e
HS2	54.14 bc	46.64 e	42.28 f-h	47.69 b
HS3	47.32 de	42.61 fg	43.50 f	44.48 c
HS4	46.57 e	35.72 kl	37.80 jk	40.03 de
HS5	59.81 a	53.39 c	53.53 c	55.58 a
HS6	51.81 c	42.04 f-h	39.90 h-j	44.58 c
HS7	42.71 fg	38.23 ij	40.46 g-i	40.46 d
HS8	60.64 a	56.01 b	51.78 c	56.15 a
HS9	35.58 k-m	43.42 f	42.50 fg	40.50 d
HS10	29.50 o	41.67 f-h	32.84 n	34.67 f
Mean (A)	46.87 a	43.16 b	41.39 c	
	Second season (2021)			
Control (DW)	39.40 l-n	43.28 hi	42.09 i-k	41.59 d
HS1	50.21 c-e	31.40 t	33.73 rs	38.45 e
HS2	50.79 cd	43.83 hi	40.89 j-l	45.17 c
HS3	42.20 ij	40.25 j-m	42.19 ij	41.55 d
HS4	44.50 h	33.28 r-t	35.40 p-r	37.73 e
HS5	58.60 a	52.08 c	55.00 b	55.22 a
HS6	48.63 d-f	37.05 o-q	37.57 n-p	41.08 d
HS7	40.89 j-l	36.97 o-q	38.37 m-o	38.74 e
HS8	54.72 b	46.74 fg	47.01 fg	49.49 b
HS9	39.95 k-m	48.30 ef	45.33 gh	44.53 c
HS10	32.58 st	46.85 fg	35.17 qr	38.20 e
Mean (A)	45.68 a	41.82 b	41.16 b	

PS1= STS at 0.4 ppm + sucrose 10%, PS2= AgNO3 at 10.0 ppm + sucrose 10%, HS10 sucrose 4%, HS2= boric acid at 200 ppm + sucrose 4%, HS3= 8-HQS at 300 ppm + sucrose 4%, HS4= AOA at 250 ppm + sucrose 4%, HS5= 8-HQS + AOA + sucrose 4%, HS6= boric acid + 8-HQS + sucrose 4%, HS70= boric acid + AOA + sucrose 4%, HS8= boric acid + 8-HQS + AOA + sucrose 4%, HS9= rosemary extract at 25% + sucrose 2%, HS10= thyme extract at 25% + sucrose 2%.

46.9 and 45.7 g/flower, respectively in 2020 and 2021. The lowest values were recorded when the flowers were pulsed in a distilled water solution (41.4 and 41.2 g/flower in 2020 and 2021, respectively). There was no significant difference between pulsing the flowers in a solution of PS2 (41.8 g/flower) and using distilled water in the second season only.

Regarding the effect of holding solution, it can be said that holding in HS8 or HS5 solutions resulted in the highest water loss in both seasons. Only in the first season, there was no significant difference between them, while in the second one, HS5 was significantly higher than HS8. In the first and second seasons, the results were 56.1 and 49.4 g/flower for HS8 and 55.5 and 55.2 g/flower for HS5 respectively.

As for the effect of interaction, the highest water loss was obtained by pulsing in PS1 then holding in either HS8 (60.6 and 54.7 g/flower) or HS5 (59.8 and 58.6 g/flower in 2020 and 2021, respectively). However, in the first season, there was no significant difference between these two combined treatments. In contrast, in the second season, when combined with a holding solution containing HS5, it resulted in a significantly higher water loss compared to the combination of HS8. The lowest significant water loss was obtained by pulsing in PS1 followed by holding in HS10 in the first season (29.5 g/flower) and PS2 followed by HS1 only in the second one (31.4 g/flower).

Water balance

Regarding the impact of pulsing solutions on the water balance of carnation cut flowers, the data presented in Table 4 revealed that PS2 exhibited superiority in this regard, recording the highest values of

Table 4 - Effect of pulsing and holding solutions and their interaction on water balance (g/flower) of *Dianthus caryophyllus* cv. Turbo cut flowers during 2020 and 2021 seasons

Holding solutions (B)	Pulsing solutions (A)			
	PS1	PS2	DW	Mean (B)
		First season (2020)		
Control (DW)	-1.71 m	-4.69 n	-5.40 no	-3.93 f
HS1	-1.52 lm	2.43 j	0.79 k	0.57 e
HS2	3.21 h-j	3.59 g-j	4.53 f-i	3.78 d
HS3	4.87 e-g	6.34 c-e	5.35 d-f	5.52 b
HS4	4.00 f-i	4.95 e-g	3.17 ij	4.04 cd
HS5	-0.11 kl	3.71 g-j	0.58 k	1.39 e
HS6	4.68 f-h	4.65 f-i	6.64 cd	5.32 b
HS7	4.00 f-i	4.54 f-i	5.44 d-f	4.66 bc
HS8	6.97 bc	9.45 a	8.37 ab	8.26 a
HS9	-6.27 op	-5.62 n-p	-4.97 no	-5.62 g
HS10	-2.70 m	-7.11 p	-2.89 m	-4.23 f
Mean (A)	1.40 b	2.02 a	1.96 a	
		Second season (2021)		
Control (DW)	-0.98 m	-4.82 o	-7.99 q	-4.60 e
HS1	-0.79 m	6.83 ij	2.38 k	2.81 d
HS2	7.96 gh	8.01 gh	7.63 gh	7.87 c
HS3	11.54 c	10.35 e	8.31 g	10.07 b
HS4	7.67 gh	9.29 f	7.46 hi	8.14 c
HS5	2.44 k	6.43 j	0.61 l	3.16 d
HS6	9.29 f	11.35 cd	10.70 de	10.45 b
HS7	7.54 h	7.63 gh	9.27 f	8.15 c
HS8	13.98 b	19.89 a	14.46 b	16.11 a
HS9	-8.40 q	-8.52 q	-5.80 p	-7.57 g
HS10	-3.46 n	-10.20 r	-2.99 n	-5.55 f
Mean (A)	4.25 b	5.11 a	4.00 c	

PS1= STS at 0.4 ppm + sucrose 10%, PS2= AgNO3 at 10.0 ppm + sucrose 10%, HS10 sucrose 4%, HS2= boric acid at 200 ppm + sucrose 4%, HS3= 8-HQS at 300 ppm + sucrose 4%, HS4= AOA at 250 ppm + sucrose 4%, HS5= 8-HQS + AOA + sucrose 4%, HS6= boric acid + 8-HQS + sucrose 4%, HS70= boric acid + AOA + sucrose 4%, HS8= boric acid + 8-HQS + AOA + sucrose 4%, HS9= rosemary extract at 25% + sucrose 2%, HS10= thyme extract at 25% + sucrose 2%.

2.0 g/flower and 5.1 g/flower in 2020 and 2021, respectively. Pulsing solution containing distilled water occupied the second position without significant differences in the first season only (1.9 g/flower).

Regarding the effect of holding solutions, HS8 resulted in the highest significant positive values in both seasons (8.2 and 16.1 g/flower in 2020 and 2021, respectively). The lowest values were obtained when using HS9, which resulted in negative values of -5.6 g/flower and -7.5 g/flower in the first and second seasons, respectively.

A significant interaction between pulsing and holding solutions was observed. Pulsing in PS2 then holding in HS8 seemed to be the most effective treatment resulting in the highest positive values (9.4 and 19.8, in 2020 and 2021, respectively. The lowest values, on the other hand, were obtained when using any pulsing solution followed by HS9, HS10, or HS1. Specifically, pulsing the flowers in PS2 followed by holding them in HS10 resulted in the lowest values in this regard, measuring -7.1 g/flower and -10.2 g/flower in the first and second seasons, respectively.

In this regard, Bhanushree and Rao (2015) conducted a research on *Gerbera jamesonii* cv. Lomborgini and reported that the application of $AgNO_3$ at 20 ppm resulted in an increase in water uptake and water loss. Khella *et al.* (2018) reported that water uptake of *Limonium sinuatum* cv. Girlie Wings cut flowers was enhanced by STS at 500 mg/l for 1/2 h or by STS at 500 mg/l for 1/4 h followed by $AgNO_3$ at 500 mg/l for 1/2 h. In a study conducted by Kazaz *et al.* (2020) on cut hydrangeas, it was found that the application of 8-HQS at 200 mg/l resulted in an improvement in solution uptake compared to the control group. These findings align with the results reported by Elgimabi (2014) on *Rosa damascena* cv. Trigintipetala and Usha *et al.* (2014) on *Cymbidium hybrid* cv. Red Princess.

Determination of pigments and sugars

Pigments content

The pulsing solution containing PS1 recorded the highest values of chlorophyll a (0.349 and 0.354 mg/g f.w.), chlorophyll b (0.234 and 0.241 mg/g f.w.) and carotenoids (0.184 and 0.182 mg/g f.w.) in both seasons, respectively. The lowest values for chlorophyll a, chlorophyll b, and carotenoids were observed when using distilled water, with recorded values of 0.293 and 0.297, 0.218 and 0.214, and 0.133 and 0.143 in the first and second seasons, respectively (Tables 5, 6, and 7).

Concerning the effect of holding solutions, HS8 resulted in the highest values of chlorophyll a (0.626 and 0.641 mg/g f.w.), chlorophyll b (0.435 and 0.434 mg/g f.w.) and carotenoids (0.236 and 0.247 mg/g f.w.) in both seasons, respectively. It could be noticed that the lowest values in terms of chlorophyll a (0.167 and 0.171 mg/g f.w.) and carotenoids (0.110 and 0.116 mg/g f.w.) in both 2020 and 2021seasons were obtained by using a holding solution containing HS9, while HS10 produced the lowest values in case of chlorophyll b (0.105 and 0.116 mg/g f.w. in 2020 and 2021 respectively). In general, all holding solution formulations involving HS9, HS10 or distilled water resulted in the lowest values for the measured parameters.

Combined treatment of PS2 in addition to HS8 resulted in the highest significant values in terms of chlorophyll a (0.642 and 0.655 mg/g f.w.) and carotenoids (0.238 and 0.255 mg/g f.w.) and occupied the second rank in case of chlorophyll b with values of 0.468 and 0.466 in 2020 and 2021, respectively. On the other hand, the highest values of chlorophyll b were obtained when using PS1 in combination with HS8 (0.481 and 0.485 mg/g f.w. in 2020 and 2021, respectively).

PS1 combined with HS9 gave the lowest values in terms of chlorophyll a, while pulsing and holding in distilled water resulted in the lowest values of chlorophyll b (0.052 and 0.059 mg/g f.w.) and carotenoids (0.062 and 0.060 mg/g f.w.) in both seasons.

In a similar context, Badawy *et al.* (2016) conducted a study on Chrysanthemum cut flowers cv. Royal Accent and reported that $AgNO_3$ exhibited the least decrease in chlorophyll content. Khella *et al.* (2018) reported that STS at 500 mg/l for 1/2 h or STS at 500 mg/l for 1/4 h followed by $AgNO_3$ 500 mg/l for 1/2 h enhanced pigments content of *Limonium sinuatum* cv. Girlie Wings cut flowers. The same results were reported by Elgimabi (2014) on *Rosa damascena* cv. Trigintipetala.

Total sugars content

The data presented in Table 8 clearly show that pulsing cut carnations in PS1 resulted in the highest percentage of sugars, with recorded values of 28.0% and 28.5% in 2020 and 2021, respectively. Following closely in the second position, a solution of PS2 showed a percentage of 27.7% in 2020 (not being significantly different from the highest) and 28.0% in

Table 5 - Effect of pulsing and holding solutions and their interaction on chlorophyll a (mg/g f.w.) of *Dianthus caryophyllus* cv. Turbo cut flowers during 2020 and 2021 seasons

Holding solutions (B)	Pulsing solutions (A)			
	PS1	PS2	DW	Mean (B)
		First season (2020)		
Control (DW)	0.250 t	0.281 r	0.143 z	0.225 h
HS1	0.267 s	0.323 o	0.247 t	0.279 g
HS2	0.353 l	0.383 k	0.314 p	0.350 e
HS3	0.480 d	0.463 e	0.327 no	0.423 b
HS4	0.395 j	0.440 f	0.288 q	0.374 d
HS5	0.329 mn	0.398 j	0.187 w	0.305 f
HS6	0.416 h	0.429 g	0.430 g	0.425 b
HS7	0.408 i	0.410 i	0.333 m	0.383 c
HS8	0.636 b	0.642 a	0.601 c	0.626 a
HS9	0.120 [	0.212 u	0.170 y	0.167 j
HS10	0.186 w	0.196 v	0.178 x	0.187 i
Mean (A)	0.349 b	0.380 a	0.293 c	
		Second season (2021)		
Control (DW)	0.255 r	0.279 p	0.139 y	0.224 h
HS1	0.264 q	0.334 m	0.243 s	0.280 g
HS2	0.355 l	0.403 k	0.330 m	0.363 e
HS3	0.483 d	0.454 e	0.334 m	0.424 b
HS4	0.406 jk	0.458 e	0.295 o	0.386 c
HS5	0.329 m	0.417 gh	0.190 v	0.312 f
HS6	0.420 g	0.413 hi	0.440 f	0.424 b
HS7	0.405 jk	0.408 ij	0.323 n	0.379 d
HS8	0.650 b	0.655 a	0.618 c	0.641 a
HS9	0.131 z	0.213 t	0.169 x	0.171 j
HS10	0.197 u	0.199 u	0.184 w	0.193 i
Mean (A)	0.354 b	0.385 a	0.297 c	

PS1= STS at 0.4 ppm + sucrose 10%, PS2= AgNO3 at 10.0 ppm + sucrose 10%, HS10 sucrose 4%, HS2= boric acid at 200 ppm + sucrose 4%, HS3= 8-HQS at 300 ppm + sucrose 4%, HS4= AOA at 250 ppm + sucrose 4%, HS5= 8-HQS + AOA + sucrose 4%, HS6= boric acid + 8-HQS + sucrose 4%, HS70= boric acid + AOA + sucrose 4%, HS8= boric acid + 8-HQS + AOA + sucrose 4%, HS9= rosemary extract at 25% + sucrose 2%, HS10= thyme extract at 25% + sucrose 2%.

2021 (being significantly different from the highest). Conversely, the lowest values were observed when using distilled water, with percentages of 25.8% and 26.0% in 2020 and 2021, respectively.

When considering the influence of holding solutions, it was evident that HS8 outperformed other treatments in terms of total sugars, resulting in the highest values in both seasons (47.5% and 48.3% in 2020 and 2021, respectively). Conversely, HS9 exhibited a negative effect, leading to the lowest sugar content (11.4% and 11.7%).

Regarding the combined treatments, PS2 in addition to HS8 produced the highest values, recording 52.0% and 54.6% in 2020 and 2021, respectively. On the other hand, when distilled water was combined with HS9, the lowest values were observed, with percentages of 10.5% and 11.1% in 2020 and 2021, respectively.

These results align with the findings of Badawy *et al.* (2016), who reported that $AgNO_3$ exhibited the highest total carbohydrate content in Chrysanthemum cut flowers cv. Royal Accent. Additionally, Khella *et al.* (2018) demonstrated that STS at 500 mg/l for 1/2 h enhanced the total carbohydrate percentage of *Limonium sinuatum* cv. Girlie Wings cut flowers, followed by the treatment with STS at 500 mg/l for 1/4 h and $AgNO_3$ at 500 mg/l for 1/2 h. Similarly, Chore *et al.* (2020) investigated *Gladiolus grandiflorus* L. cv. Fado and found a significant increase in total soluble sugars in spikes pulsed with 600 ppm 8-HQS + 5% sucrose compared to the control. These results are consistent with the findings

Table 6 - Effect of pulsing and holding solutions and their interaction on chlorophyll b (mg/g f.w.) of *Dianthus caryophyllus* cv. Turbo cut flowers during 2020 and 2021 seasons

Holding solutions (B)	Pulsing solutions (A)			
	PS1	PS2	DW	Mean (B)
	First season (2020)			
Control (DW)	0.105 x	0.174 r	0.052 \	0.110 j
HS1	0.156 t	0.184 q	0.154 t	0.165 h
HS2	0.206 p	0.251 n	0.260 m	0.239 f
HS3	0.396 d	0.423 c	0.294 l	0.371 b
HS4	0.217 o	0.357 ef	0.222 o	0.266 e
HS5	0.185 q	0.300 k	0.143 u	0.209 g
HS6	0.362 e	0.316 i	0.338 g	0.339 c
HS7	0.294 l	0.309 j	0.332 h	0.312 d
HS8	0.481 a	0.468 b	0.356 f	0.435 a
HS9	0.079 [	0.163 s	0.119 w	0.120 i
HS10	0.088 z	0.098 y	0.128 v	0.105 k
Mean (A)	0.234 b	0.277 a	0.218 c	
	Second season (2021)			
Control (DW)	0.127 n-p	0.181 j-m	0.059 q	0.122 h
HS1	0.172 k-n	0.181 j-m	0.168 k-n	0.174 g
HS2	0.208 i-k	0.260 gh	0.240 g-i	0.236 e
HS3	0.398 bc	0.437 ab	0.285 fg	0.373 b
HS4	0.230 h-j	0.368 cd	0.215 h-k	0.271 d
HS5	0.188 j-l	0.284 fg	0.144 l-o	0.205 f
HS6	0.367 cd	0.324 d-f	0.324 d-f	0.338 c
HS7	0.291 e-g	0.337 de	0.316 d-f	0.315 c
HS8	0.485 a	0.466 a	0.350 cd	0.434 a
HS9	0.088 pq	0.171 k-n	0.124 n-p	0.128 h
HS10	0.095 o-q	0.130 m-p	0.123 n-p	0.116 h
Mean (A)	0.241 b	0.285 a	0.214 c	

PS1= STS at 0.4 ppm + sucrose 10%, PS2= AgNO3 at 10.0 ppm + sucrose 10%, HS10 sucrose 4%, HS2= boric acid at 200 ppm + sucrose 4%, HS3= 8-HQS at 300 ppm + sucrose 4%, HS4= AOA at 250 ppm + sucrose 4%, HS5= 8-HQS + AOA + sucrose 4%, HS6= boric acid + 8-HQS + sucrose 4%, HS70= boric acid + AOA + sucrose 4%, HS8= boric acid + 8-HQS + AOA + sucrose 4%, HS9= rosemary extract at 25% + sucrose 2%, HS10= thyme extract at 25% + sucrose 2%.

of Elgimabi (2014) on *Rosa damascena* cv. Trigintipetala and Bhanushree and Rao (2015) on *Gerbera jamesonii* cv. Lomborgini.

The present study exhibited the beneficial role of certain chemicals used in pulsing or holding solutions of carnation cut flowers either individually or in combinations. The application of these chemicals resulted in a significant increase in the vase life of cut flowers, more than doubling its duration. Furthermore, these treatments also had a positive impact on water relations and chemical composition, including chlorophylls a, b, carotenoids, and total sugars. It is well known that the vase life of cut carnation is considered one of the most vital traits for florists (Panwar *et al.*, 2022). Finger and Barbosa (2006) summarized the factors affecting the longevity of cut flowers as (1) their tender nature, (2) a lot of stresses leading to water uptake reduction, stored carbohydrates exhaustion and respiration increment (3) the harmful effects of ethylene. Otherwise, the vase life of cut flowers is affected basically by ethylene which enhances the senescence of many cut flowers as well as microorganisms which reduce the amount of water uptake by causing a vascular blockage (Zencirkiran, 2010). Halevy (1987) reported that carnation cut flowers are highly sensitive to ethylene either endogenously produced or exogenously applied. Carnation is known to be highly susceptible to the buildup of microorganisms in the vase solution or at the cut ends of the flower stems. This accumulation can result in blockage of the vascular system and ultimately reduce the vase life of the flowers (Van Doorn

Table 7 - Effect of pulsing and holding solutions and their interaction on carotenoids (mg/g f.w.) of Dianthus caryophyllus cv. Turbo cut flowers during 2020 and 2021 seasons

Holding solutions (B)	Pulsing solutions (A)			
	PS1	PS2	D.W.	Mean (B)
		First season (2020)		
Control (DW)	0.139 n	0.179 k	0.062 t	0.127 i
HS1	0.179 k	0.207 i	0.123 pq	0.170 h
HS2	0.189 j	0.211 hi	0.131 o	0.177 f
HS3	0.230 de	0.237 ab	0.133 o	0.200 c
HS4	0.210 hi	0.232 b-d	0.125 p	0.189 e
HS5	0.188 j	0.214 h	0.119 q	0.174 g
HS6	0.234 a-d	0.226 ef	0.232 cd	0.231 b
HS7	0.222 fg	0.219 g	0.148 m	0.196 d
HS8	0.236 a-c	0.238 a	0.234 a-d	0.236 a
HS9	0.091 s	0.172 l	0.065 t	0.110 j
HS10	0.110 r	0.135 no	0.086 s	0.110 j
Mean (A)	0.184 b	0.207 a	0.133 c	
		Second season (2021)		
Control (DW)	0.129 n	0.201 i	0.060 r	0.130 h
HS1	0.182 j	0.207 h	0.127 n	0.172 g
HS2	0.200 i	0.218 g	0.148 l	0.189 e
HS3	0.216 g	0.230 de	0.142 m	0.196 c
HS4	0.199 i	0.235 c	0.143 m	0.192 d
HS5	0.182 j	0.235 cd	0.131 n	0.182 f
HS6	0.225 f	0.216 g	0.246 b	0.229 b
HS7	0.228 ef	0.209 h	0.158 k	0.198 c
HS8	0.236 c	0.255 a	0.249 b	0.247 a
HS9	0.089 p	0.179 j	0.079 q	0.116 i
HS10	0.118 o	0.141 m	0.093 p	0.118 i
Mean (A)	0.182 b	0.212 a	0.143 c	

PS1= STS at 0.4 ppm + sucrose 10%, PS2= AgNO3 at 10.0 ppm + sucrose 10%, HS10 sucrose 4%, HS2= boric acid at 200 ppm + sucrose 4%, HS3= 8-HQS at 300 ppm + sucrose 4%, HS4= AOA at 250 ppm + sucrose 4%, HS5= 8-HQS + AOA + sucrose 4%, HS6= boric acid + 8-HQS + sucrose 4%, HS70= boric acid + AOA + sucrose 4%, HS8= boric acid + 8-HQS + AOA + sucrose 4%, HS9= rosemary extract at 25% + sucrose 2%, HS10= thyme extract at 25% + sucrose 2%.

et al., 1991). Hence, eliminating ethylene production and microorganism accumulation is a vital procedure to prolong the vase life of cut carnations. All solutions containing sucrose showed a great influence compared to control (distilled water only) or solutions with only 2.0% sucrose. This observation aligns with the well-known fact that sucrose, as a source of sugar, plays a crucial role in preservative solutions. The use of sucrose in pulsing solution or as a constituent of vase solution may extend the vase life of the flowers by improving the water balance, stimulating flower opening or by delaying the senescence due to lower synthesis of ethylene, as observed in cut carnation (Finger and Barbosa, 2006).

This study clearly highlights the significance of using integrated silver thiosulfate (STS) in post-harvest solutions. In this regard, treatment with silver thiosulfate complex (STS) delayed the senescence of attached and detached petals of *Dianthus caryophyllus* cv. Barbara (Ichimura and Niki, 2014). STS is highly mobile in the xylem of carnation flowers and may become a practical treatment for carnation flowers (Reid and Kofranek, 1980). Hashemabadi (2014) revealed that STS treatment extended the longevity of cut carnation 'Tempo' flowers by reducing oxidative stress, improving the antioxidant system, reducing bacterial populations and delaying flowering. Chemicals such as STS, are also effective at the receptor level and prevent the binding of ethylene (Ebrahimzadeh *et al.*, 2008).

Using $AgNO_3$ in a pulsing solution of carnation cut flowers showed a great influence. In this regard,

Table 8 - Effect of pulsing and holding solutions and their interaction on total sugars (%) of Dianthus caryophyllus cv. Turbo cut flowers during 2020 and 2021 seasons

Holding solutions (B)	Pulsing solutions (A)			
	PS1	PS2	DW	Mean (B)
		First season (2020)		
Control (DW)	20.43 o	18.89 p	9.83 t	16.38 i
HS1	23.29 n	22.69 n	23.30 n	23.09 h
HS2	29.19 jk	23.43 n	29.95 j	27.52 f
HS3	40.87 d	39.72 de	30.28 ij	36.96 b
HS4	30.16 ij	33.40 g	27.68 l	30.41 e
HS5	25.79 m	28.75 kl	21.26 o	25.27 g
HS6	35.63 f	31.12 hi	39.01 e	35.25 c
HS7	31.72 h	30.00 ij	32.91 g	31.55 d
HS8	47.70 b	52.01 a	42.89 c	47.53 a
HS9	11.02 s	12.82 r	10.55 st	11.46 k
HS10	13.04 r	12.24 r	16.22 q	13.83 j
Mean (A)	28.08 a	27.73 a	25.81 b	
		Second season (2021)		
Control (DW)	21.39 o	19.20 p	9.98 u	16.86 h
HS1	24.71 lm	23.77 mn	22.75 no	23.74 g
HS2	31.08 hi	24.35 l-n	31.10 hi	28.84 e
HS3	42.73 c	40.24 de	31.64 g-i	38.20 b
HS4	29.13 jk	33.06 g	29.10 jk	30.43 d
HS5	25.64 l	27.55 k	21.87 o	25.02 f
HS6	34.95 f	31.76 g-i	38.94 e	35.22 c
HS7	30.38 ij	28.63 k	32.61 gh	30.54 d
HS8	48.48 b	54.67 a	41.86 cd	48.34 a
HS9	11.23 s-u	12.88 rs	11.10 tu	11.74 j
HS10	14.43 qr	12.06 st	16.01 q	14.17 i
Mean (A)	28.56 a	28.02 b	26.09 c	

PS1= STS at 0.4 ppm + sucrose 10%, PS2= AgNO3 at 10.0 ppm + sucrose 10%, HS10 sucrose 4%, HS2= boric acid at 200 ppm + sucrose 4%, HS3= 8-HQS at 300 ppm + sucrose 4%, HS4= AOA at 250 ppm + sucrose 4%, HS5= 8-HQS + AOA + sucrose 4%, HS6= boric acid + 8-HQS + sucrose 4%, HS70= boric acid + AOA + sucrose 4%, HS8= boric acid + 8-HQS + AOA + sucrose 4%, HS9= rosemary extract at 25% + sucrose 2%, HS10= thyme extract at 25% + sucrose 2%.

$AgNO_3$ is used as an antimicrobial, since the Ag^+ ion replaces the hydrogen cations (H^+) on surface proteins in the cell membranes of bacteria, which leads to loss of membrane integrity and causes cell death (Feng *et al*., 2000).

This study exhibited a positive influence of 8-HQS addition to the holding solution in extending vase life, enhancing water relations (uptake and balance) and chemical constituents of cut carnation flowers, this effect may be explained by the positive role of 8-HQS as a germicide agent. Preservative solutions of carnation cut flowers containing 8-HQS showed a strong inhibitory effect on fungi, yeasts and bacteria (El-Ashwah, 2011). Numerous authors have corroborated this fact, supporting the use of 8-hydroxyquinoline sulfate (8-HQS) in vase solutions to effectively reduce microbial counts. One such study by Madhuri *et al.* (2016) demonstrated that the addition of 8-HQS resulted in the lowest microbial counts in vase solutions. Kabari and Soleimandarabi (2019) on Alstroemeria cut flowers observed the lowest bacterial population in vase solution in the treatment of 200 8-HQS mg/l. In addition, 8-HQS is considered an ethylene synthesis inhibitor (Ebrahimzadeh *et al.*, 2008).

To explain the positive role of AOA in the present study, Son *et al.* (1995) reported that AOA appeared to inhibit the activities of arginine decarboxylase and ACC synthase. Ethylene production was significantly decreased by AOA at concentrations over 100 mg/l, the decline in ACC content was observed after using 100 or 150 mg/l AOA (Karimi *et al.*, 2012). Aminooxyacetic acid (AOA) inhibits the synthesis of ethylene by reducing the competitive and irreversible activity of 1-Aminocyclopropane-1-carboxylic acid (ACC) synthase, reducing the amount of substrate for ACC oxidase, and therefore the conversion of ACC to ethylene (Finger and Barbosa, 2006).

Boric acid also showed a promising influence when it was integrated into the holding solution of cut carnation flowers, this could be explained by its role in preventing the early rise in ethylene production and considerably improving carnation vase life (Serrano *et al.*, 2001).

While many studies have highlighted the positive impact of natural extracts as a component in preservative solutions, such as El-Ashwah (2011) on carnation cv. Domingo, Khenizy *et al.* (2014) on *Gypsophila paniculata* L. "Perfecta,", Zaky *et al.* (2014) on carnation cv. America, and Hashemabadi *et al.* (2017) on carnation cv. White Liberty, our study did not observe a similar effect. The lack of satisfactory results in our study regarding the effectiveness of rosemary and thyme extracts may be attributed to the fact that these extracts were used in combination with sucrose at 2.0% only, without the addition of any germicidal agents to the solution. The presence of sugar in the solution without germicidal agents can promote the growth of microorganisms, since these extracts alone may not possess sufficient biocidal properties to effectively control microorganisms (Armitage and Laushman, 2003). Therefore, the outcomes of using natural extracts in our study were not as promising. In future research, it is recommended to consider incorporating germicidal agents along with these extracts, particularly when using extracts obtained through water extraction methods. This approach can help enhance the antimicrobial efficacy and overall performance of natural extracts as preservatives in cut flower solutions.Adam

In conclusion, it is highly recommended to pulse carnation cv. Turbo cut flowers in a solution containing $AgNO_3$ at 10.0 ppm + sucrose 10% for a duration of 15 minutes, followed by holding them in a solution of BoA + 8-HQS + AOA + Suc 4% to extend the vase life of the flowers, enhancing water uptake and maintaining water balance. Additionally, this preservative solution effectively reduces chlorophyll degradation and preserves the content of carbohydrates throughout the postharvest period.

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