

The Effects of Pre- and Post-Storage Pulsing Treatments on Storage Performance and Vase Life of *Rosa hybrida* L. cv. 'Magnum' Cut Roses

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Abstract

In this study, the effects of 7% sucrose pulsing treatments applied before and after storage on the storage performance and vase life of cut roses (*Rosa hybrida* L. cv. 'Magnum') were investigated. The experimental treatments consisted of: (A) control group, in which cut roses were held in tap water at $20 \pm 2^\circ\text{C}$ for 24 hours; (B) post-storage treatment, in which roses were subjected to a 7% sucrose solution containing 0.5 mL NaOCl adjusted to pH 5.5–6.5 at $20 \pm 2^\circ\text{C}$ for 6 hours; and (C) pre-storage treatment, in which roses were treated with the same 7% sucrose solution (0.5 mL NaOCl, pH 5.5–6.5) at $20 \pm 2^\circ\text{C}$ for 24 hours prior to storage. All cut roses were then stored in solution at 4°C and 70–75% relative humidity (RH) for up to 28 days (A: tap water; B and C: 0.5 mL NaOCl + low pH solution). Vase life evaluations were conducted at five different storage intervals (I: unstored flowers, II: 7 days, III: 14 days, IV: 21 days, and V: 28 days of storage), and each vase life assessment was carried out for 12 days under controlled conditions ($20 \pm 2^\circ\text{C}$, $60 \pm 10\%$ RH, and approximately $12 \mu\text{mol m}^{-2} \text{s}^{-1}$ light intensity). During storage and vase life, significant differences were observed among treatments for all evaluated parameters, including relative fresh weight (%), solution uptake ($\text{mL day}^{-1} \text{g}^{-1} \text{FW}$), pH variation in vase solution, electrical conductivity ($\mu\text{S cm}^{-1}$), relative water content (g), respiratory rate ($\text{mL CO}_2 \text{kg}^{-1} \text{h}^{-1}$), ethylene production (ppm), leaf and petal color (h°), visual quality (1–5 scale), flower opening (0–5 scale), neck bending ($^\circ$), leaf chlorophyll content (mg L^{-1}), petal carbohydrate content (%), vase life, and statistical analysis (JMP 5.0.1).

Overall, treatment C (pre-storage 7% sucrose application) was found to be more effective for maintaining quality during up to 21 days of wet storage. In addition, treatment B (post-storage application at 7 and 14 days of storage) showed positive effects on vase-life performance. Vase life and quality parameters of cut roses decreased progressively with increasing storage duration. In terms of longevity and visual quality retention, the order of vase-life performance was $\text{I} > \text{II} > \text{III} > \text{IV} > \text{V}$.

INTRODUCTION

The rose is regarded as a plant of considerable social significance due to its pleasant fragrance, vivid colors, and symbolic role in the expression of emotions. Its native distribution area is reported to encompass Anatolia and Central Asia (the Caucasus region) (Özçelik, 2013). The rose exhibits a wide geographical distribution extending from China to Northern Europe. The quality and vase life of roses are significantly influenced by both cultivation conditions and the environmental conditions to which ornamental plants are exposed during the post-purchase period in consumers' residences. Considering all contributing factors, studies have demonstrated that more than half of the vase life of roses is determined by cultivation conditions, whereas the remaining portion is associated with post-harvest practices and storage conditions (Vlad and Vlad, 2017; Horibe and Yamada, 2017).

Extending the post-harvest longevity of cut flowers is of considerable importance for maintaining their ornamental value and marketability. In order to prolong vase life, it is essential to understand the factors influencing floral longevity before harvest, during harvest, and throughout the post-harvest period. Post-

harvest handling involves a series of processes aimed at preparing cut flowers for the market. These processes include harvesting, conditioning, pre-cooling, pulsing (solution uptake), grading, bundling, packaging, palletizing, storage, transportation, and marketing. Various biocides, holding and pulsing solutions, plant growth regulators, and controlled storage temperatures are commonly applied to enhance the vase life of cut flowers (Gupta and Dubey, 2018). Furthermore, studies have demonstrated that both cooling during transportation and the initial quality of roses, which is largely dependent on cultivation practices, exert significant effects on quantitative and qualitative losses throughout the rose supply chain (Grisotto and Caixeta-Filho, 2018).

Roses can be stored under conditions of 4–5°C and 75% relative humidity (RH) in water-based storage systems. The uptake of water by cut flowers can be enhanced through the addition of 1% sucrose, germicidal agents, and citric acid to the vase solution. During storage, transportation, and vase-life periods, roses may undergo various morphological changes, including stem bending, flower opening, and floral senescence (Kazaz et al., 2003).

Roses are commonly packaged in bundles consisting of 20 stems and secured using string or rubber bands. Under dry storage conditions, roses may be preserved for up to two weeks when wrapped in polyethylene materials to minimize water loss and maintained at temperatures close to 0°C (Senapati et al., 2016). In *Rosa hybrida* L. cv. 'Tereasa', treatments involving vase solutions of different pH levels in the presence of 2% sucrose were reported to exhibit a strong correlation with vase life over two growing seasons. Lowering the pH of the vase solution was found to help maintain higher osmotic potential, delay senescence, and extend floral longevity (Shanan, 2017). Furthermore, applications involving essential oils have been shown to prolong the vase life of 'Bacara' cut roses by reducing bacterial proliferation within the stem tissues (Salehi Salmi et al., 2018). Different concentrations of 1-methylcyclopropene (1-MCP) applied to *Rosa hybrida* cv. 'First Red' were reported to reduce post-storage decay and significantly extend vase life. Compared with the control treatment, the 'First Red' cultivar could be stored for up to 21 days in a 1% sucrose solution at 4°C and 70% relative humidity (Demircioğlu et al., 2018). In cut garden roses, vase solutions containing $\text{Al}_2(\text{SO}_4)_3$, ethanol, and sucrose resulted in extended vase life and enhanced water uptake capacity (Mladenović et al., 2018). In *Rosa hybrida* cv. 'Samurai', continuous treatments involving energy sources such as sucrose, mannitol, and ATP demonstrated positive effects on vase longevity, with 3% sucrose treatment resulting in the longest vase life of 11.4 days (Shafeii et al., 2019). Similarly, in 'Blush' cut roses, the application of 3% sucrose combined with 100 ppm HQC during three different production seasons (March–April, June–July, and September–October) positively influenced bud opening index, solution uptake, distilled water consumption, time required for bud opening, and overall vase life (Qureshi et al., 2019). For 'Grand Gala' cut roses, a vase solution consisting of 2% sucrose, 1000 $\mu\text{g mL}^{-1}$ *Nyctanthes arbor-tristis* extract, and 2% pepper extract was identified as the most effective treatment based on physiological responses associated with flower longevity (Mishra et al., 2019). Moreover, the application of Zamzam water, either alone at different concentrations or in combination with magnetic water (50% magnetic water + 50% Zamzam water), improved water uptake, fresh weight retention, and vase life in *Rosa* spp. cv. 'Top Secret' (Hegazy and Ibrahim, 2019). In cut roses, the combination of 2% sucrose and 15 ppm salicylic acid (SA)

was found to provide superior flower quality and the longest vase life among tested preservative solutions (Aryal et al., 2019). In the 'Osiana' rose cultivar, the most favorable storage conditions were achieved at 22°C under wet storage conditions. Furthermore, EthylBloc® applications exceeding 1.0 g m⁻³ significantly prolonged vase life and maintained fresh mass during the first two days, even in the presence of ethylene (Cordeiro et al., 2020). Likewise, preservative solutions containing 0.5 g dm⁻³ Al₂(SO₄)₃, 4% ethanol, and 20 g dm⁻³ sucrose extended the vase life of *Rosa hybrida* L. cultivars 'Red Sky' and 'Blizzard' by 17%, 18%, and 19%, respectively, compared with deionized water treatments (Gebremedhin, 2020). Overall, sucrose-containing preservative solutions have consistently been identified as among the most effective treatments for extending the vase life of cut flowers. Nevertheless, both pre-harvest and post-harvest factors play critical roles in determining floral longevity, and maintaining optimal environmental and handling conditions is essential for maximizing vase life (Sharma and Thakur, 2020).

In this study, *Rosa hybrida* L. cv. 'Magnum', a commercially valuable red rose cultivar cultivated under greenhouse conditions in Mersin and widely exported to international markets, was investigated. The study aimed to evaluate post-harvest storage and vase-life preservation strategies, with particular emphasis on the effects of a 7% sucrose pulsing treatment applied before and after storage on the storage performance and vase life of cut roses.

MATERIALS and METHOD

Material

This study was conducted in 2019 in the cold storage facilities of the Department of Horticulture, Faculty of Agriculture, Çukurova University. The experimental material consisted of *Rosa hybrida* L. cv. 'Magnum' cut roses cultivated under soilless culture conditions in a private commercial greenhouse operated by Naturel Tarım. The roses were harvested on 22 June 2019, and a total of 90 bunches (450 stems; 20 stems per bunch) with an average stem length of 55 cm were obtained for the experiment. The physiological changes occurring during storage and vase-life periods were evaluated in the Postharvest Physiology Laboratory of the Department of Horticulture, Faculty of Agriculture, Çukurova University.

Method

Rosa hybrida L. cv. 'Magnum' cut roses were harvested at the standard commercial maturity stage during the early morning hours and transported to the laboratory within one hour without water uptake treatment. The roses used in the experiment were divided into three treatment groups: (A) a control group maintained in tap water, (B) a group subjected to a 7% sucrose pulsing treatment (containing sodium hypochlorite and adjusted to low pH) after storage, and (C) a group subjected to the same 7% sucrose pulsing treatment before storage. During both storage and vase-life evaluations, the vase solutions used for groups B and C contained 0.5 mL sodium hypochlorite (5% NaOCl), and the pH was

adjusted to 5.5–6.5 using acetic acid (CH_3COOH). In contrast, cut roses in the control group were maintained exclusively in tap water throughout the storage and vase-life periods.

Wet storage was applied to all three groups of cut roses for a duration of four weeks. Physical and chemical analyses, as well as vase life evaluations, were conducted at regular 7 day intervals throughout the storage period. Vase life was defined as the duration from the first day the cut flowers were placed in the vase solution until they lost their primary ornamental value, as indicated by wilting, petal browning, and discoloration (van Doorn, 1997; Jin et al., 2006).

After storage, cut roses in group B were immersed in a 7% sucrose solution for 6 hours. During the wet storage experiment, cut roses were placed in vase solutions and stored at $4 \pm 1^\circ\text{C}$ and 70–75% relative humidity (RH). The vase water of the stored cut roses was replaced once a week, and stem ends were recut under water during each solution change. Wet storage was maintained for a total of four weeks.

For vase life evaluation, flowers were transferred to controlled environmental conditions ($20 \pm 2^\circ\text{C}$, $60 \pm 10\%$ RH, and daylight with an approximate light intensity of $12 \mu\text{mol m}^{-2} \text{s}^{-1}$). Vase life assessments were conducted both before and after storage. During this period, vase solutions were renewed every four days, and stem ends were recut under water; observations were continued until senescence of the flowers. For groups B and C, vase solutions contained 0.5 mL NaOCl (5%) and were adjusted to pH 5.5–6.5 using CH_3COOH , whereas flowers in group A were maintained in tap water.

Throughout storage, analyses were performed at 7 day intervals, while vase-life evaluations were conducted at 0, 4, 8, and 12 days. All vase solutions were prepared using tap water; additionally, 0.5 mL NaOCl was added per liter of tap water for all groups except the control (A) to prevent microbial deterioration, and pH was adjusted using CH_3COOH . The ‘Magnum’ cut rose cultivar was placed in 500 mL glass vases for vase-life evaluation during the experimental period.

The vase life of cut roses was categorized into five evaluation periods: (I) vase life of unstored flowers, (II) vase life after 7 days of storage, (III) vase life after 14 days of storage, (IV) vase life after 21 days of storage, and (V) vase life after 28 days of storage.

During both storage and vase life periods in ‘Magnum’ cut roses, a range of physiological, biochemical, and quality-related parameters were evaluated. These included relative fresh weight (%; Chamani et al., 2005), solution uptake ($\text{mL day}^{-1} \text{g}^{-1}$ fresh weight; Chamani et al., 2005), pH variation in vase solutions, electrical conductivity changes in vase solutions ($\mu\text{S cm}^{-1}$), and relative water content (g). In addition, respiratory rate ($\text{mL CO}_2 \text{kg}^{-1} \text{h}^{-1}$; Uygun, 2003) and ethylene production (ppm) were measured. Color attributes were assessed using flower and petal color measurements (h°), while visual quality was evaluated using a 1–5 scale. Flower opening was scored on a 0–5 scale (Wang et al., 2004; Ma et al., 2005), and neck bending was recorded according to established criteria (Anonymous, 2017; Anonymous, 2020). Chlorophyll content in leaves (mg L^{-1} total chlorophyll; Ađar et al., 1997) and carbohydrate content in petals, including individual sugars such as glucose (%; Chinnici et al., 2005; Kaplan et al.,

2017), were also determined. Finally, vase life was recorded, and all data were subjected to statistical analysis using JMP software (version 5.0.1).

The experiment was arranged in a randomized factorial experimental design. All analyses were conducted in three replicates for each treatment, with five flowers per replicate. The data obtained from the experiment were analyzed using JMP software (version 5.0.1), and mean comparisons were performed using the Least Significant Difference (LSD) test at a significance level of $p < 0.05$.

RESULTS and DISCUSSION

Relative Fresh Weight

In 'Magnum' cut roses, relative fresh weight exhibited a general decreasing trend across all treatments during the storage period. During storage, relative fresh weight values in treatments B and C were similar to each other, whereas both treatments showed higher values compared with treatment A. Comparison of relative fresh weight across treatments and storage periods revealed statistically significant differences in 'Magnum' cut roses. Treatments B and C were grouped together statistically, while storage durations formed distinct groups. When treatment effects and storage periods were evaluated jointly, statistically significant differences were also observed (Table 1). Across the I, II, III, IV, and V vase life stages, relative fresh weight exhibited a general decreasing trend in all treatments during the vase life period. In 'Magnum' cut roses, relative fresh weight values at each vase life stage (I–V) were similar in treatments B and C, whereas both treatments consistently showed higher values than treatment A. When treatments were compared across the II, III, IV, and V vase life stages, statistically significant differences were observed. Overall, both treatments and vase-life stages were grouped separately based on statistical analysis. In addition, when treatments and vase-life periods (II–V) were evaluated jointly in 'Magnum' cut roses, statistically significant differences were also determined (Table 1).

The relative fresh weight of 'Magnum' cut roses exhibited a decreasing trend during both storage and vase-life periods. A similar reduction in relative fresh weight during vase life has also been reported in 'First Red' cut roses (Chamani et al., 2005; Demircioğlu, 2010; Demircioğlu et al., 2018). In contrast, various post-harvest treatments have been shown to improve relative fresh weight retention in different rose cultivars. For instance, holding solutions containing 5 mg L⁻¹ NG and 2% sucrose in 'Tineke' cut roses, 20 ppm STS combined with 7.5% sucrose in 'Cardinal' cut roses, 12% sucrose + 15 mg L⁻¹ NaOCl in 'Cardinal' cut roses, and distilled or tap water supplemented with 6% sucrose in Dutch Hybrid roses were reported to significantly enhance relative fresh weight (Kader, 2012; Hayat et al., 2012; Awan et al., 2017; Chaudhary and Khanal, 2018). Similarly, improved relative fresh weight responses were observed in cut roses treated with vase solutions containing 250 mg L⁻¹ 8-HQS combined with either 2% sucrose or 2% glucose (Sudaria et al., 2017). In 'Top Secret' cut roses, Zamzam water and its various concentrations resulted in the highest relative fresh weight values; however, a decline in relative fresh weight during vase life was still observed across two growing seasons (Hegazy and Ibrahim, 2019).

Table 1
Changes in relative fresh weight (%) of 'Magnum' cut roses during storage and at five different vase life stages

SP (days)	Treatment			Means
	A	B	C	
7	100,93 bc	102,66 ab	104,12 a	102,57 a
14	94,78 efg	100,23 c	99,68 c	98,23 b
21	93,50 fg	97,07 d	96,13 de	95,57 c
28	93,64 fg	92,94 g	94,89 ef	93,82 d
Means	95,71 b	98,22 a	98,71 a	
LSD _{0,05} T: 0,97, LSD _{0,05} SP: 1,12, LSD _{0,05} T x SP: 1,93.				
VL I (days)	Treatment			Means
	A	B	C	
0	-	-	-	-
4	83,83	98,89	96,47	93,06
8	83,26	85,18	95,95	88,13
12	82,94	91,65	93,7	89,43
Means	83,35 b	91,91 a	95,37 a	
*(4,16), **(NS), *** (NS)				
VL II (days)	Treatment			Means
	A	B	C	
0	100,93 a	102,66 a	104,12 a	102,57 a
4	80,64 d	94,57 b	90,68 bc	88,63 b
8	79,71 d	93,24 bc	89,31 bc	87,42 b
12	72,14 e	89,14 bc	87,67 c	82,98 c
Means	83,36 b	94,90 a	92,94 a	
*(2,94), **(3,40), *** (5,89)				
VL III (days)	Treatment			Means
	A	B	C	
*(2,07), **(2,39), *** (4,14)				

SP (days)	Treatment			Means
	A	B	C	
0	94,78 b	100,23 a	99,68 a	98,23 a
4	71,20 e	85,36 cd	89,58 c	82,05 c
8	87,13 cd	87,94 cd	87,31 cd	87,46 b
12	84,15 d	85,32 cd	86,71 cd	85,40 b
Means	84,32 b	89,71 a	90,82 a	
*(2,43), **(2,80), ***(4,85)				
VL IV (days)	Treatment			Means
	A	B	C	
0	93,50 ab	97,07 a	96,13 a	95,57 a
4	60,52 e	82,21 cd	88,90 bc	77,21 c
8	82,76 d	84,80 cd	88,14 c	85,24 b
12	85,48 cd	82,44 d	85,49 cd	84,47 b
Means	80,57 c	86,63 b	89,66 a	
*(2,47), **(2,85), ***(4,93)				
VL V (days)	Treatment			Means
	A	B	C	
0	93,64 ab	92,94 ab	94,89 a	93,82 a
4	66,64 f	90,31 bc	88,44 cd	81,80 c
8	87,41 cd	84,85 de	86,55 cd	86,27 b
12	87,73 cd	81,95 e	87,06 cd	85,58 b
Means	83,85 b	87,51 a	89,23 a	
*(2,07), **(2,39), ***(4,14)				

*LSD_{0,05}T, **LSD_{0,05} VL, ***LSD_{0,05}T x VL. Mean values followed by same small letters do not differ significantly according to LSD test ($p < 0.05$). SP: Storage period, VL: Vase life, T: Treatment. 'NS' no significant. A) Control group subjected to tap water uptaking, B) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) after storage and C) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) before storage.

Solution Uptake

It was observed that solution uptake values in 'Magnum' cut roses generally decreased across all treatments during the storage period. While solution uptake values in treatments B and C were similar to each other, both were higher than those recorded in treatment A. In the first year of the experiment, statistically significant differences were found among treatments for solution uptake in 'Magnum' cut roses. Treatments B and C were grouped together statistically. When storage durations were compared, statistically significant differences were also detected. The 14-, 21-, and 28-day storage periods were classified within the same statistical group (Table 2). During the vase life periods I, II, III, IV, and V, solution uptake in 'Magnum' cut roses was measured across all treatments and showed an increase on day 4, followed by a decline on subsequent days. Across the II, III, and IV vase-life stages, solution uptake values in treatments B and C were similar throughout the evaluation period, whereas both treatments consistently exhibited higher values than treatment A. When treatments and vase life stages (I–V) were compared, statistically significant differences were observed in solution uptake of 'Magnum' cut roses. Overall, treatments and vase-life periods were classified into separate statistical groups. In addition, when treatments and vase-life stages were evaluated jointly, statistically significant differences were also detected, particularly at the III and IV vase-life stages (Table 2).

Solution uptake in 'Magnum' cut roses generally showed a decreasing trend during both storage and vase life periods across all treatments. In the literature, improved solution uptake has been reported under various postharvest treatments and conditions in different rose cultivars. Higher solution uptake values were observed in 'Sonia' cut roses treated with 8-HQS and sucrose combined with 8-HQS, in 'First Red' cut roses harvested at different times (March and May), and in treatments involving increased concentrations of tea seed saponins. In addition, pulsing treatments with 200 ppm HQC + 3% sucrose, as well as vase solutions containing glucose in combination with biocides such as 8-HQS or STS (e.g., 250 mg L⁻¹ 8-HQS + 2% sucrose and 250 mg L⁻¹ 8-HQS + 2% glucose), have been reported to enhance solution uptake in 'First Red' cut roses compared with other treatments (Ichimura et al., 1999; Ichimura et al., 2003; Jain et al., 2005; Ichimura et al., 2005a; Jain et al., 2007; Sudaria et al., 2017). Furthermore, higher solution uptake has been associated with vase solutions adjusted to pH 3.0 and 4.6 in the presence of 2% sucrose in 'Tereasa' cut roses. Treatments including 100–200 ppm 8-HQS and 5% sucrose + 300 ppm citric acid in 'Top Secret' cut roses, as well as 2% sucrose + 15 ppm citric acid and 4% sucrose + 30 ppm citric acid in cut roses of the 'Red Rosa' variety, have also been reported to improve solution uptake. In addition, storage at 6°C under wet storage conditions resulted in higher solution uptake compared with the 'Krohen' variety and room temperature storage (Shanan, 2017; Kinfé et al., 2018; Aryal et al., 2019; Kadhim and Alwan, 2020).

Table 2
Changes in solution uptake (mL day⁻¹ g⁻¹ FW) during storage and at five different vase-life stages in 'Magnum' cut roses

SP (days)	Treatment			Means
	A	B	C	
7	0,8	0,77	0,77	0,78 a
14	0,4	0,48	0,75	0,54 b
21	0,52	0,57	0,53	0,54 b
28	0,42	0,53	0,54	0,50 b
Means	0,54	0,59	0,65	
LSD _{0,05} T: NS, LSD _{0,05} SP: 0,10, LSD _{0,05} T x SP: NS				
VL I (days)	Treatment			Means
	A	B	C	
0	-	-	-	-
4	1,32	1,48	1,57	1,46 a
8	0,73	1,12	1,27	1,04 b
12	0,39	0,57	0,68	0,54 c
Means	0,81 b	1,06 a	1,17 a	
*(0,15), **(0,15), ***(NS)				
VL II (days)	Treatment			Means
	A	B	C	
0	0,80	0,77	0,77	0,78 b
4	0,87	1,11	1,13	1,04 a
8	0,59	1,1	0,94	0,88 ab
12	0,58	1,1	0,95	0,88 ab
Means	0,71 b	1,02 a	0,95 a	
*(0,14), **(0,16), ***(NS)				
VL III (days)	Treatment			Means
	A	B	C	
*(0,10), **(0,12), ***(NS)				

SP (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	0,40 f	0,48 ef	0,75 c-e	0,54 c
4	0,81 b-d	1,11 b	1,80 a	1,24 a
8	0,52 d-f	0,86 bc	1,03 bc	0,80 b
12	0,24 f	0,92 bc	1,04 bc	0,74 b
Means	0,49 c	0,84 b	1,16 a	
*(0,16), **(0,18), *** (0,32)				
VL IV (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	0,52 d	0,57 d	0,53 d	0,54 c
4	0,44 de	1,06 a	1,04 ab	0,85 a
8	0,31 e	0,83 c	0,85 bc	0,66 b
12	0,30 e	0,58 d	0,81 c	0,57 bc
Means	0,39 b	0,76 a	0,81 a	
*(0,10), **(0,11), *** (0,19)				
VL V (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	0,42	0,53	0,54	0,50 c
4	0,62	1,11	0,98	0,90 a
8	0,4	0,83	0,69	0,64 b
12	0,28	0,57	0,55	0,46 c
Means	0,43 b	0,76 a	0,69 a	
*(0,10), **(0,12), *** (NS)				

*LSD_{0,05}T, **LSD_{0,05} VL, ***LSD_{0,05}T x VL. Mean values followed by same small letters do not differ significantly according to LSD test ($p < 0.05$). SP: Storage period, VL: Vase life, T: Treatment. 'NS' no significant. A) Control group subjected to tap water uptaking, B) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) after storage and C) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) before storage.

pH and Electrical Conductivity

It was observed that pH variation in the vase solution was lower during the storage period, and a greater reduction in acidity occurred in 'Magnum' cut roses. During storage, the pH difference in the vase solution was lower in treatment A compared with treatments B and C; however, an overall decrease in vase solution acidity was observed (Table 3). Across the I, II, III, IV, and V vase life stages, pH difference values in the vase solution were generally similar in treatments B and C, whereas both treatments exhibited lower values compared with treatment A (Table 3).

In 'Magnum' cut roses, pH changes were observed in the vase solution, and a general decrease in solution acidity occurred during the evaluation period. Previous studies have reported that vase solutions typically become more acidic by approximately 0.6–0.9 pH units across different species and treatments (Ahmad and Dole, 2014). Semi-strength electrolyzed anode water adjusted to pH 5 or 6 has been shown to be as effective as aqueous HCl solutions (pH 2 or 3) in extending the vase life of cut roses (Ohta and Harada, 2000). In addition, benzyladenine (BA) application was reported to prolong the vase life of 'Baccara' cut roses maintained in pH 6 vase solutions and to reduce overall solution uptake (Pompodakis et al., 2004). The low pH of 8-hydroxyquinoline sulfate (8-HQS) vase solutions has also been found to be beneficial for cut roses by inhibiting microbial growth and thereby improving post-harvest performance (Sudaria et al., 2017). Conversely, in 'Tereasa' cut roses evaluated over two summer seasons, increased pH levels were associated with a negative effect on flower longevity (Shanan, 2017).

Table 3
Changes in vase solution pH during storage and at five different
vase life stages in 'Magnum' cut roses

SP (days)	Treatment			Means
	A	B	C	
0	0,00 ab	0,00 ab	0,00 ab	0,00 a
7	-0,67 ef	-0,84 efg	-0,84 efg	-0,78 c
14	0,15 a	-0,92 efg	-0,94 fg	-0,57 b
21	-0,26 bc	-1,09 g	-0,63 de	-0,66 bc
28	-0,37 cd	-0,92 efg	-0,86 efg	-0,71 bc
Means	-0,23 a	-0,75 b	-0,65 b	
LSD _{0,05} T: 0,13, LSD _{0,05} SP: 0,17, LSD _{0,05} T x SP: 0,29				
VL I (days)	Treatment			Means
	A	B	C	
0	0,00 a	0,00 a	0,00 a	0,00 a
4	-1,23 d	-1,86 e	-1,81 e	-1,63 c
8	-1,20 cd	-1,99 e	-1,87 e	-1,69 c
12	-0,53 b	-1,13 cd	-1,03 c	-0,89 b
Means	-0,74 a	-1,24 b	-1,18 b	
*(0,09), **(0,11), *** (0,18)				
VL II (days)	Treatment			Means
	A	B	C	
0	0,00 a	0,00 a	0,00 a	0,00 a
4	-0,44 b	-0,16 ab	-0,17 ab	-0,26 b
8	-0,46 b	-1,31 c	-1,49 c	-1,09 d
12	-0,15 ab	-0,50 b	-1,18 c	-0,61 c
Means	-0,26 a	-0,49 b	-0,71 c	
*(0,18), **(0,21), *** (0,37)				
VL III (days)	Treatment			Means
	A	B	C	
*(0,20), **(0,23), *** (NS)				

SP (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	0,00 a	0,00 a	0,00 a	0,00 a
4	-0,50 cde	-1,66 g	-1,27 f	-1,14 d
8	-0,07 ab	-0,41 cd	-0,40 cd	-0,29 b
12	-0,33 bc	-0,76 e	-0,66 de	-0,58 c
Means	-0,23 a	-0,71 b	-0,58 b	
*(0,16), **(0,18), *** (0,31)				
VL IV (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	0,00 a	0,00 a	0,00 a	0,00 a
4	-0,73 c	-1,47 ef	-1,14 d	-1,11 c
8	-0,31 ab	-1,16 de	-0,42 bc	-0,63 b
12	-0,68 c	-1,67 f	-1,14 d	-1,16 c
Means	-0,43 a	-1,07 c	-0,68 b	
*(0,16), **(0,18), *** (0,32)				
VL V (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	0,00	0,00	0,00	0,00 a
4	-0,28	-0,77	-0,69	-0,58 bc
8	-0,35	-0,86	-0,68	-0,63 c
12	-0,19	-0,47	-0,44	-0,37 b
Means	-0,20 a	-0,53 b	-0,45 b	
*(0,20), **(0,23), *** (NS)				

*LSD_{0,05}T, **LSD_{0,05} VL, ***LSD_{0,05}T x VL. Mean values followed by same small letters do not differ significantly according to LSD test ($p < 0.05$). SP: Storage period, VL: Vase life, T: Treatment. 'NS' no significant. A) Control group subjected to tap water uptaking, B) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) after storage and C) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) before storage.

During storage, electrical conductivity (EC) difference values in the vase solution of 'Magnum' cut roses were relatively low; however, overall EC variation in the vase solution was found to be higher. During storage, EC difference values in treatments A and C were similar, whereas both were lower than those observed in treatment B (Table 4). Across the II, IV, and V vase life stages, EC difference values in the vase solution were generally comparable between treatments A and C, while treatment B exhibited higher values. Overall, EC variation in the vase solution remained elevated during the vase life period (Table 4). It was also observed that increased EC difference values during both storage and vase-life periods corresponded to higher conductivity levels in the vase solution of 'Magnum' cut roses across the two experimental years. Similarly, Ahmad and Dole (2014) reported that the electrical conductivity of all preservative solutions increased during the vase life period.

Table 4
Changes in solution EC during storage and at five different vase life stages in 'Magnum' cut roses

SP (days)	Treatment			Means
	A	B	C	
0	0	0	0	0,00 a
7	2,67	-12	-16,67	-8,67 b
14	-15,33	-10,33	-14	-13,22 bc
21	-12,33	-11	-12	-11,78 bc
28	-24,67	-12	-14	-16,89 c
Means	-9,93	-9,07	-11,33	
LSD _{0,05} T: NS, LSD _{0,05} SP: 7,55, LSD _{0,05} T x SP: NS				
VL I (days)	Treatment			Means
	A	B	C	
0	0	0,00	0,00	0,00 a
4	-16	3,67	-12	-8,11 ab
8	-32,67	-10,67	-9	-17,44 b
12	-71,67	-31,33	-30,67	-44,56 c
Means	-30,08 b	-9,58 a	-12,92 a	
*(9,85), **(11,37), ***(NS)				
VL II (days)	Treatment			Means
	A	B	C	
0	0	0	0	0,00 a
4	-9,67	-2	-21,67	-11,11 b
8	-6,33	-6	-17	-9,78 ab
12	-44,33	-21,33	-31	-32,22 c
Means	-15,08	-7,33	-17,42	
*(NS), ***(9,91), ***(NS)				
VL III (days)	Treatment			Means
	A	B	C	
*(NS), ***(NS), ***(30,05)				

SP (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	0,00 a	0,00 a	0,00 a	0,00 a
4	-28,67 abc	-27,00 abc	-37,33 bcd	-31,00 b
8	-60,00 cd	-2,67 ab	-1,33 a	-21,33 b
12	-69,33 d	5,00 a	-1,33 a	-21,89 b
Means	-39,50 b	-6,17 a	-10,00 a	
*(17,71), **(20,45), *** (35,43)				
VL IV (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	0	0,00	0,00	0,00 a
4	-25,67	-13,67	-9,67	-16,33 b
8	-27	-10,67	-9,33	-15,67 b
12	-64,67	-39	-48,33	-50,67 c
Means	-29,33 b	-15,83 a	-16,83 a	
*(8,72), **(9,72), *** (NS)				
VL V (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	0,00 ab	0,00 ab	0,00 ab	0
4	-1,67 ab	-23,33 abc	-17,00 ab	-14
8	-49,33 c	-15,00 ab	-4,67 ab	-23
12	-26,00 bc	6,33 a	-29,67 bc	-16,44
Means	-19,25	-8	-12,83	
*(NS), **(NS), *** (30,05)				

*LSD_{0,05}T, **LSD_{0,05} VL, ***LSD_{0,05}T x VL. Mean values followed by same small letters do not differ significantly according to LSD test ($p < 0.05$). SP: Storage period, VL: Vase life, T: Treatment. 'NS' no significant. A) Control group subjected to tap water uptaking, B) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) after storage and C) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) before storage.

Relative Water Content

Relative water content values were found to be low in 'Magnum' cut roses during the storage period. In general, relative water content decreased across all treatments during storage (Table 5). Similarly, during the vase life stages I, II, III, IV, and V, relative water content showed a general declining trend. Relative water content values in treatments B and C were similar throughout the vase life period, whereas both treatments consistently exhibited higher values compared with treatment A (Table 5). Overall, relative water content decreased during vase life in 'Magnum' cut roses.

Previous studies have also reported comparable findings. Dry storage of 'Mercedes' cut roses at 2°C and 95% RH for 10 days without water did not significantly reduce leaf water content, whereas wet stored roses exhibited higher petal water content (Faragher et al., 1984). In addition, elevated CO₂ conditions in 'First Red' and 'Twingo' cut roses were found to delay the onset of declines in relative water content (Urban et al., 2002). Various postharvest treatments have also been reported to maintain or increase relative water content in cut roses. These include STS application in 'Happy Hour', pre-harvest salicylic acid and CaCl₂ treatments in 'Sweet Life', 1-MCP treatments in 'Happy Hour' and 'Bordeaux', salicylic acid and 1-MCP in 'Vega', hydrogen-rich water at appropriate doses in 'Cardinal', L-proline treatments in 'Lovely Red', cummin essential oil (150 mg L⁻¹) and 400 mg L⁻¹ 8-HQS in 'Angelina', coating applications (1.5 and 3.0 mL) in 'Avalanche', silica nanoparticle-based preservative solutions in 'Gold Star' (yellow), ABA and nitric oxide donor sodium nitroprusside treatments, as well as moringa (*Moringa oleifera*) leaf and seed extracts in 'Upper Class'. Furthermore, preharvest silicon applications (soil or foliar) have been shown to enhance and maintain relative water content in leaves and petals during post-harvest storage (Hassan and Ali, 2014; Abdolmaleki et al., 2015; Hassan, 2016; Geerdink et al., 2016; Ren et al., 2017; Di Stasio et al., 2018; Mirjalili et al., 2018; Pinsetta Junior et al., 2019; El-Serafy, 2019; Deng et al., 2019; Hassan et al., 2020; Geerdink et al., 2020).

Table 5
Changes in relative water content during storage and at five different vase life stages in 'Magnum' cut roses

SP (days)	Treatment			Means
	A	B	C	
0	0,8	0,8	0,8	0,80 a
7	0,8	0,79	0,79	0,80 a
14	0,81	0,82	0,77	0,80 a
21	0,79	0,79	0,8	0,79 ab
28	0,76	0,78	0,78	0,77 b
Means	0,79	0,8	0,79	
LSD _{0,05} T: NS, LSD _{0,05} SP: 0,02, LSD _{0,05} T x SP: NS				
VL I (days)	Treatment			Means
	A	B	C	
0	0,80 a	0,80 a	0,80 a	0,80 a
4	0,79 ab	0,78 abc	0,76 bcd	0,77 b
8	0,74 cd	0,77 a-d	0,79 ab	0,77 b
12	0,66 e	0,74 cd	0,73 d	0,71 c
Means	0,75	0,77	0,77	
*(NS), **(0,02), *** (0,04)				
VL II (days)	Treatment			Means
	A	B	C	
0	0,80 a	0,79 ab	0,79 ab	0,80 a
4	0,75 cd	0,79 ab	0,77 bcd	0,77 b
8	0,67 e	0,76 bcd	0,78 abc	0,74 c
12	0,67 e	0,73 d	0,77 bc	0,73 c
Means	0,72 b	0,77 a	0,78 a	
*(0,02), ** (0,02), *** (0,03)				
VL III (days)	Treatment			Means
*(0,03), ** (0,03), *** (NS)				

SP (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	0,81 ab	0,82 a	0,77 c	0,80 a
4	0,72 e	0,78 bc	0,78 bc	0,76 b
8	0,63 f	0,75 cde	0,76 cd	0,72 c
12	0,66 f	0,73 de	0,76 cd	0,72 c
Means	0,71 b	0,77 a	0,77 a	
*(0,02), **(0,02), *** (0,04)				
VL IV (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	0,79 bc	0,79 bc	0,80 ab	0,79 a
4	0,75 de	0,82 a	0,76 cd	0,78 a
8	0,60 h	0,71 g	0,72 fg	0,68 b
12	0,54 i	0,71 g	0,74 ef	0,66 c
Means	0,67 b	0,76 a	0,76 a	
*(0,01), **(0,01), *** (0,02)				
VL V (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	0,76	0,78	0,78	0,77 a
4	0,73	0,77	0,79	0,76 a
8	0,69	0,8	0,78	0,75 a
12	0,67	0,68	0,74	0,70 b
Means	0,71 b	0,76 a	0,77 a	
*(0,03), **(0,03), *** (NS)				

*LSD_{0,05}T, **LSD_{0,05} VL, ***LSD_{0,05}T x VL. Mean values followed by same small letters do not differ significantly according to LSD test ($p < 0.05$). SP: Storage period, VL: Vase life, T: Treatment. 'NS' no significant. A) Control group subjected to tap water uptaking, B) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) after storage and C) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) before storage.

Respiration Rate

It was observed that respiratory rate values were relatively high during the storage period in 'Magnum' cut roses. Respiratory rate exhibited fluctuations across all treatments. While respiratory rate values in treatments B and C were similar to each other, both were higher than those recorded in treatment A (Table 6). Across the I, II, III, IV, and V vase life stages, respiratory rate also showed general fluctuations throughout the evaluation period. In this context, treatments B and C displayed similar values, whereas treatment A generally exhibited lower respiratory rates (Table 6).

Overall, respiratory rate values were comparatively lower during storage but increased during the vase-life period, with noticeable variations among treatments. Similar findings have been reported in previous studies, where 'Duett', 'Golden Gate', and 'Cream Prophyta' cut roses exhibited lower respiratory rates compared to flowers harvested in the afternoon (Tshwenyane and Bishop, 2010). It has also been demonstrated that respiration rate decreases under optimal temperature conditions, thereby extending plant longevity (Çelikel, 2013). In 'Magnum' cut roses, respiration rate was reduced during cold storage at + 4°C, whereas an increase was observed during vase life ($20 \pm 2^\circ\text{C}$). Likewise, respiration in 'Moonlight' cut roses increased up to the third day of vase life and then declined (Hong and Viet, 2016). In 'First Red' cut roses, respiration rate increased during dry storage, decreased during wet storage, and subsequently increased again during vase life following both storage conditions (Demircioğlu, 2010; Demircioğlu et al., 2018). Furthermore, significantly lower respiration rates were reported in the 'Red Rosa' variety under 6°C wet storage conditions compared with the 'Krohen' variety and room temperature storage (Kadhim and Alwan, 2020). Similarly, EthylBloc® treatment was found to reduce respiratory activity in 'Osiana' roses after 36 hours under different storage conditions (Cordeiro et al., 2020).

Table 6
Changes in respiratory rate during storage and at five different vase
life stages in 'Magnum' cut roses

SP (days)	Treatment			Means
	A	B	C	
0	7,95 cd	7,95 cd	7,95 cd	7,95 c
7	7,18 d	12,64 ab	13,03 ab	10,95 ab
14	12,82 ab	12,53 ab	12,64 ab	12,66 a
21	6,85 d	9,82 bcd	12,22 ab	9,63 bc
28	13,88 a	8,16 cd	11,30 abc	11,12 ab
Means	9,74	10,22	11,43	
LSD _{0,05} T: NS, LSD _{0,05} SP: 2,28, LSD _{0,05} T x SP: 3,95				
VL I (days)	Treatment			Means
	A	B	C	
0	7,95 a-d	7,95 a-d	7,95 a-d	7,95
4	7,65 bcd	9,53 abc	10,53 abc	9,24
8	11,30 a	5,03 d	9,18 abc	8,5
12	7,22 cd	7,43 cd	10,87 ab	8,51
Means	8,53	7,49	9,63	
*(NS), **(NS), *** (3,38)				
VL II (days)	Treatment			Means
	A	B	C	
0	7,18 d	12,64 ab	13,03 a	10,95 a
4	9,60 bcd	7,65 cd	6,85 d	8,03 c
8	13,37 a	8,51 cd	8,50 cd	10,13 ab
12	7,65 cd	7,30 d	10,48 abc	8,48 bc
Means	9,45	9,02	9,72	
*(NS), ** (1,82), *** (3,16)				
VL III (days)	Treatment			Means
	A	B	C	
*(NS), ** (1,83), *** (3,17)				

SP (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	12,82 b	12,53 b	12,64 b	12,66
4	13,16 b	9,28 b	10,21 b	10,88
8	20,25 a	9,29 b	9,77 b	13,1
12	13,53 b	14,10 b	9,55 b	12,39
Means	14,94 a	11,30 b	10,54 b	
*(2,41), **(NS), ***(4,82)				
VL IV (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	6,85 d	9,82 cd	12,22 bc	9,63 b
4	16,26 a	13,30 abc	12,23 bc	13,93 a
8	15,01 ab	16,46 a	13,69 ab	15,05 a
12	16,26 a	13,94 ab	13,77 ab	14,65 a
Means	13,59	13,38	12,98	
*(NS), **(2,07), *** (3,58)				
VL V (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	13,88 ab	8,16 d	11,30 bcd	11,12 b
4	12,62 abc	10,25 cd	10,86 bcd	11,24 b
8	14,47 a	15,34 a	12,42 abc	14,08 a
12	3,48 e	8,18 d	9,48 cd	7,05 c
Means	11,11	10,48	11,02	
*(NS), **(1,83), *** (3,17)				

*LSD_{0,05}T, **LSD_{0,05} VL, ***LSD_{0,05}T x VL. Mean values followed by same small letters do not differ significantly according to LSD test ($p < 0.05$). SP: Storage period, VL: Vase life, T: Treatment. 'NS' no significant. A) Control group subjected to tap water uptaking, B) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) after storage and C) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) before storage.

Ethylene Production Amount

It was observed that ethylene production levels were low during the storage period in 'Magnum' cut roses. However, ethylene production exhibited fluctuations across all treatments during storage. While ethylene production values in treatments B and C were similar, both were lower than those recorded in treatment A (Table 7). Across the I, II, III, IV, and V vase life stages, ethylene production also showed general fluctuations throughout the evaluation period. In this context, treatments B and C displayed comparable values, whereas treatment A consistently exhibited higher ethylene production (Table 7).

Overall, ethylene production fluctuated during both storage and vase-life periods in 'Magnum' cut roses. Previous studies have demonstrated that the application of STS and 1-MCP effectively inhibits ethylene production in cut roses (cv. Baroness) (Hassan et al., 2004). Ethylene exposure has also been reported to reduce vase life in 'First Red' cut roses (Chamani et al., 2005). Moreover, cultivar-dependent differences in ethylene sensitivity have been observed, with 'Cardinal' showing greater sensitivity than 'Samantha' (Ma et al., 2005). Postharvest treatments such as sucrose combined with 8-HQS have been reported to cause only minor differences in ethylene production trends between 'Delilah' and 'Sonia' roses; however, ethylene sensitivity was higher in 'Delilah' compared with 'Sonia' (Ichimura et al., 2005b). Additionally, differential responses to ethylene exposure have been reported between 'Samantha' and 'Cardinal' cultivars (Ma et al., 2005).

Table 7
Changes in ethylene production amount during storage and at
five different vase life stages in 'Magnum' cut roses

SP (days)	Treatment			Means
	A	B	C	
0	18,80 a	18,80 a	18,80 a	18,80 a
7	6,70 e	4,99 e	6,00 e	5,90 d
14	9,60 cd	11,82 bc	11,67 bc	11,03 c
21	19,02 a	13,45 b	10,60 c	14,35 b
28	6,84 de	5,12 e	5,56 e	5,84 d
Means	12,19 a	10,84 b	10,53 b	
LSD _{0,05} T: 1,27, LSD _{0,05} SP: 1,64, LSD _{0,05} T x SP: 2,84				
VL I (days)	Treatment			Means
	A	B	C	
0	18,80 f	18,80 f	18,80 f	18,80 d
4	42,22 d	29,19 e	31,97 e	34,46 c
8	80,38 b	94,84 a	94,49 a	89,90 a
12	94,08 a	53,12 c	47,28 d	64,83 b
Means	58,87 a	48,99 b	48,13 b	
*(2,88), **(3,32), ***(5,75)				
VL II (days)	Treatment			Means
	A	B	C	
0	6,70 g	4,99 g	6,00 g	5,90 d
4	12,07 f	12,86 f	18,51 e	14,48 c
8	32,60 d	18,73 e	17,33 e	22,89 b
12	73,87 a	55,51 b	47,98 c	59,12 a
Means	31,31 a	23,02 b	22,46 b	
*(1,69), **(1,96), ***(3,39)				
VL III (days)	Treatment			Means
	A	B	C	
*(2,72), **(3,14), ***(5,43)				

SP (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	9,60 d	11,82 d	11,67 d	11,03 c
4	17,79 d	17,58 d	19,34 d	18,24 c
8	80,14 b	39,65 c	49,60 c	56,46 b
12	95,43 a	69,38 b	39,57 c	68,13 a
Means	50,74 a	34,61 b	30,04 b	
*(7,32), **(8,46), *** (14,65)				
VL IV (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	19,02 ef	13,45 fg	10,60 g	14,35 d
4	29,19 d	18,27 ef	20,70 ef	22,72 c
8	86,12 a	31,15 d	20,89 e	46,05 b
12	68,94 b	46,72 c	36,35 d	50,67 a
Means	50,82 a	27,40 b	22,13 c	
*(3,63), **(4,19), *** (7,26)				
VL V (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	6,84 g	5,12 g	5,56 g	5,84 d
4	30,74 e	15,48 f	14,07 f	20,09 c
8	93,84 a	52,86 d	29,06 e	58,59 b
12	73,07 b	69,68 b	59,30 c	67,35 a
Means	51,12 a	35,79 b	27,00 c	
*(2,72), **(3,14), *** (5,43)				

*LSD_{0,05}T, **LSD_{0,05} VL, ***LSD_{0,05}T x VL. Mean values followed by same small letters do not differ significantly according to LSD test ($p < 0.05$). SP: Storage period, VL: Vase life, T: Treatment. 'NS' no significant. A) Control group subjected to tap water uptaking, B) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) after storage and C) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) before storage.

Leaf and Petal Color

It was observed that leaf color h° values were relatively low in 'Magnum' cut roses during the storage period. In general, leaf color h° values in treatments B and C were similar to each other, whereas both were higher than those recorded in treatment A (Table 8). Across the I, II, III, IV, and V vase life stages, leaf color h° values generally decreased during the vase life period. In this context, treatments B and C showed comparable values, while treatment A consistently exhibited lower values (Table 8). Overall, a decline in leaf color was observed in 'Magnum' cut roses during both storage and vase life. Similar reductions in leaf color during wet and dry storage, as well as during subsequent vase life, have also been reported in 'First Red' cut roses (Demircioğlu, 2010; Demircioğlu et al., 2018).

Regarding petal color, h° values were found to be lower during storage in 'Magnum' cut roses, and the bright red coloration gradually became duller and darker. Petal color h° values in treatments B and C were similar, whereas both were higher than those observed in treatment A (Table 9). Across the I, II, III, IV, and V vase life stages, petal color h° values generally decreased during vase life. In this case, treatments B and C again showed similar trends, while treatment A exhibited lower values (Table 9). Overall, a reduction in petal color quality was observed during both storage and vase life in 'Magnum' cut roses. Comparable decreases in petal color have also been reported in 'First Red' cut roses under both wet and dry storage conditions and during subsequent vase life (Demircioğlu, 2010; Demircioğlu et al., 2018). In addition, improvements in anthocyanin content have been reported in 'Passion' cut roses stored under cold conditions in polypropylene packaging and in 'Black Magic' cut roses treated with salicylic acid during vase life (Makhwana et al., 2015; Ghadimian and Danaei, 2016). Furthermore, different concentrations of sucrose and citric acid have been shown to have a significant effect on color changes over time in cut roses (Aryal et al., 2019).

Table 8
Changes in leaf color during storage and at five different vase life stages in 'Magnum' cut roses

SP (days)	Treatment			Means
	A	B	C	
0	131,34	131,34	131,34	131,34
7	133,35	133,49	131,91	132,92
14	130,92	132,5	132,2	131,87
21	132,26	131,82	132,89	132,32
28	132,41	132,65	133,24	132,77
Means	132,06	132,36	132,32	
LSD _{0,05} T: NS, LSD _{0,05} SP: NS, LSD _{0,05} T x SP: NS				
VL I (days)	Treatment			Means
	A	B	C	
0	131,34	131,34	131,34	131,34
4	133,02	133,46	133,1	133,19
8	130,29	133,44	131,98	131,9
12	114,96	132,62	131,99	126,52
Means	127,4	132,71	132,1	
*(NS), **(NS), ***(NS)				
VL II (days)	Treatment			Means
	A	B	C	
0	133,35 a	133,49 a	131,91 a	132,92 a
4	132,45 a	132,14 a	132,62 a	132,40 a
8	127,46 b	131,85 a	132,59 a	130,63 b
12	127,81 b	132,08 a	132,36 a	130,75 b
Means	130,27 b	132,39 a	132,37 a	
*(1,28), ***(1,48), ***(2,56)				
VL III (days)	Treatment			Means
	A	B	C	
*(4,83), ***(5,58), ***(9,66)				

SP (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	130,92	132,5	132,2	131,87
4	130,92	132,5	131,99	131,8
8	126,18	133,3	131,6	130,36
12	127,3	131,94	130,77	130
Means	128,83 b	132,56 a	131,64 a	
*(1,43), **(NS), *** (NS)				
VL IV (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	132,26 a	131,82 a	132,89 a	132,32 a
4	130,38 a	132,20 a	132,45 a	131,68 a
8	116,38 d	128,56 ab	129,69 ab	124,88 b
12	125,48 bc	122,43 c	132,78 a	126,90 b
Means	126,12 c	128,75 b	131,95 a	
*(2,33), **(2,69), *** (4,65)				
VL V (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	132,41 b-d	132,65 bc	133,24 b	132,77 a
4	128,34 b-e	130,80 b-d	131,43 b-d	130,19 a
8	122,81 de	146,83 a	118,68 e	129,44 ab
12	124,20 b-e	124,83 b-e	125,87 c-e	124,97 b
Means	126,94 b	133,78 a	127,31 b	
*(4,83), **(5,58), *** (9,66)				

*LSD_{0,05}T, **LSD_{0,05} VL, ***LSD_{0,05}T x VL. Mean values followed by same small letters do not differ significantly according to LSD test ($p < 0.05$). SP: Storage period, VL: Vase life, T: Treatment. 'NS' no significant. A) Control group subjected to tap water uptaking, B) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) after storage and C) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) before storage.

Table 9
Changes in petal color during storage and at five different vase
life stages in 'Magnum' cut roses

SP (days)	Treatment			Means
	A	B	C	
0	30,64	30,64	30,64	30,64 a
7	29,46	29,42	29,95	29,61 b
14	28,08	28,79	29,56	28,81 bc
21	27,33	28,16	28,68	28,06 c
28	26,49	28,25	25,7	26,81 d
Means	28,4	29,05	28,91	
LSD _{0,05} T: NS, LSD _{0,05} SP: 0,84, LSD _{0,05} T x SP: NS				
VL I (days)	Treatment			Means
	A	B	C	
0	30,64 a	30,64 a	30,64 a	30,64 a
4	29,17 a	29,51 a	30,18 a	29,62 a
8	23,09 c	25,88 b	26,61 b	25,19 b
12	18,29 d	18,19 d	21,31 c	19,26 c
Means	25,30 b	26,05 b	27,18 a	
*(1,08), **(1,25), *** (2,16)				
VL II (days)	Treatment			Means
	A	B	C	
0	29,46	29,42	29,95	29,61 a
4	28,54	29,35	29,5	29,13 a
8	22,08	26,27	27,23	25,20 b
12	19,2	19,25	18,28	18,91 c
Means	24,82	26,07	26,24	
*(NS), ** (2,43), *** (NS)				
VL III (days)	Treatment			Means
	A	B	C	
*(1,19), ** (1,38), *** (2,38)				

SP (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	28,08 ab	28,79 a	29,56 a	28,81 a
4	27,89 ab	26,64 bc	28,34 ab	27,62 a
8	20,88 e	23,90 d	25,03 cd	23,27 b
12	17,38 f	15,02 g	19,40 ef	17,27 c
Means	23,56 b	23,59 b	25,58 a	
*(1,04), **(1,20), *** (2,08)				
VL IV (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	27,33 a	28,16 a	28,68 a	28,06 a
4	27,03 a	26,80 a	26,50 a	26,78 b
8	15,41 d	17,53 c	19,60 b	17,51 c
12	9,55 e	15,47 d	17,17 cd	14,06 d
Means	19,83 c	21,99 b	22,99 a	
*(0,96), **(1,10), *** (1,91)				
VL V (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	26,49 ab	28,25 a	25,70 b	26,81 a
4	25,28 b	25,61 b	27,06 ab	25,98 a
8	11,43 e	17,15 d	19,95 c	16,18 b
12	16,73 d	17,03 d	18,38 cd	17,38 b
Means	19,98 b	22,01 a	22,77 a	
*(1,19), **(1,38), *** (2,38)				

*LSD_{0,05}T, **LSD_{0,05} VL, ***LSD_{0,05}T x VL. Mean values followed by same small letters do not differ significantly according to LSD test ($p < 0.05$). SP: Storage period, VL: Vase life, T: Treatment. 'NS' no significant. A) Control group subjected to tap water uptaking, B) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) after storage and C) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) before storage.

Visual Quality

It was observed that visual quality values were higher during the storage period in 'Magnum' cut roses, indicating that overall quality was maintained during storage. In general, visual quality values in treatments B and C were similar to each other, whereas both treatments exhibited higher values than treatment A. Across the I, II, III, IV, and V vase life stages, visual quality values generally decreased during vase life in 'Magnum' cut roses. Throughout the entire vase life period, treatments B and C showed comparable values, while both were higher than those recorded in treatment A (Fig. 1). Overall, visual quality declined in 'Magnum' cut roses during both storage and vase-life periods (Fig. 2), with a more pronounced loss observed during vase life.

Similar reductions in visual quality during both storage and vase life have also been reported in 'First Red' cut roses under wet and dry storage conditions (Demircioğlu, 2010; Demircioğlu et al., 2018). In addition, previous studies have demonstrated that visual quality is influenced by post-harvest treatments. In 'Baccara' cut roses, higher sucrose concentrations (4%) were associated with improved visual quality, while in 'Red One' cut roses, combined applications of sucrose and AgNO_3 showed beneficial effects. Moreover, variations in $\text{Al}_2(\text{SO}_4)_3$ concentration, either alone or in combination with sucrose, have been reported to affect visual quality in cut roses. Similarly, treatments such as 15 mg L^{-1} NaOCl + 12% sucrose in 'Cardinal', 2% sucrose + 15 ppm citric acid in cut roses, and preservative solutions containing optimal concentrations of $\text{Al}_2(\text{SO}_4)_3$, ethanol, and sucrose in 'Blizzard' and 'Red Sky' cultivars were found to significantly influence visual quality parameters (Pompodakis and Joyce, 2003; Mirjalili, 2015; Bajwa et al., 2016; Awan et al., 2017; Aryal et al., 2019; Gebremedhin, 2020).

Flower Opening

Flower opening values were relatively high in 'Magnum' cut roses during storage; however, opening remained generally between stage 2 (fully opened bud) and stage 3 (partially opened flower). In this context, flower opening values in treatments B and C were similar to each other, whereas both were lower than those observed in treatment A. During the storage period, stage 5 (fully open flower with visible anthers) was not observed in any treatment. Across the I, II, III, IV, and V vase life stages, flower opening generally increased during the vase-life period. However, flower opening values remained similar among all treatments throughout vase life, and complete flower opening was not achieved (Fig. 3a). In 'Magnum' cut roses, flower opening occurred both during storage and vase life. While the opening process was slow during storage, it increased rapidly during the initial days of vase life and then remained relatively stable thereafter.

Similar findings have been reported in 'First Red' cut roses, where flower opening decreased during both wet and dry storage and during subsequent vase life (Demircioğlu, 2010; Demircioğlu et al., 2018). It has also been shown that the addition of sucrose to vase solutions or storage under high light conditions can promote bud opening in cv. 'Madelon' (Kuiper et al., 1996). Furthermore, sucrose application in 'Sonia' cut roses, combinations of sucrose and hypochlorite treatments, and STS +sucrose applications

(25 ppm STS + 7.5% sucrose or 25 ppm STS alone) in 'Cardinal' cut roses have been reported to influence flower opening (Ichimura et al., 2003; Muriithi and Ouma, 2011; Hayat et al., 2012).

Neck Bending

It was observed that neck bending angle values were relatively high in 'Magnum' cut roses, while the degree of neck bending was lower during the storage period. In this context, neck bending angle values in treatments B and C were similar to each other, whereas both were higher than those recorded in treatment A. Neck bending was observed in all treatments during storage (Table 10). Across the I, II, III, IV, and V vase life stages, neck bending angle values generally decreased during the vase-life period. Treatments B and C showed similar values throughout this period, while both were higher than treatment A (Table 10). However, neck bending was present in all treatments (Fig. 3b). In 'Magnum' cut roses, neck bending developed during both storage and vase life. While bending was slight during storage, it became more pronounced during vase life and was associated with premature senescence and bud desiccation. Neck bending was most frequently observed in treatment A during both storage and vase life periods.

Similar findings have been reported in 'First Red' cut roses, where neck bending increased during both wet and dry storage as well as during subsequent vase life (Demircioğlu, 2010; Demircioğlu et al., 2018). Post-harvest neck bending is generally associated with insufficient water uptake by the flower stem. Previous studies have shown that treatments such as Satureja extract combined with distilled water + 4% sucrose at different concentrations (200, 400, and 600 ppm) in cut roses, 300 µM BA application in 'Sparkle' cut roses, distilled water + 6% sucrose and tap water + 6% sucrose treatments in Dutch Hybrid roses, and - 210 V static electricity exposure in cut roses can influence neck bending development (Kazaz, 2015; Rasool and Sae'id, 2015; Rasouli et al., 2015; Chaudhary and Khanal, 2018; Yıldız and Aydoğan, 2021).

Table 10
Changes in neck bending angle during storage and at five different
vase life stages in 'Magnum' cut roses

SP (days)	Treatment			Means
	A	B	C	
0	179,60 a	178,80 ab	179,87 a	179,42 a
7	179,00ab	178,67ab	179,47 a	179,04 a
14	176,27 cd	176,13 cd	177,27 bc	176,56 b
21	175,27 d	176,40 cd	175,67 cd	175,78 b
28	169,87 e	174,87 d	175,87 cd	173,53 c
Means	176,00 b	176,97 a	177,63 a	
LSD _{0,05} T: 0,82, LSD _{0,05} SP: 1,06, LSD _{0,05} T x SP: 1,84				
VL I (days)	Treatment			Means
	A	B	C	
0	179,60 a	179,33 a	179,53 a	179,49 a
4	175,13 b	178,93 a	178,93 a	177,67 b
8	157,67 e	174,53 bc	173,67 bc	168,62 c
12	153,33 f	168,67 d	172,00 c	164,67 c
Means	166,43 b	175,37 a	176,03 a	
*(1,27), **(1,47), *** (2,54)				
VL II (days)	Treatment			Means
	A	B	C	
0	178,67 a	178,93 a	178,93 a	178,84 a
4	163,93 c	175,07 ab	174,80 ab	171,27 b
8	149,00 d	175,67 ab	174,87 ab	166,51 c
12	142,33 d	172,87 ab	170,00 bc	161,73 d
Means	158,48 b	175,63 a	174,65 a	
*(3,46), **(4,00), *** (6,93)				
VL III (days)	Treatment			Means
	A	B	C	
*(3,45), **(3,98), *** (6,89)				

SP (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	177,60 a	176,80 a	177,33 a	177,24 a
4	163,67 cd	174,40 ab	176,07 ab	171,38 b
8	143,67 e	167,00 bc	168,13 a-c	159,60 c
12	131,33 f	154,40 d	164,00 cd	149,91 d
Means	154,07 b	168,15 a	171,38 a	
*(4,82), **(5,57), *** (9,65)				
VL IV (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	176,13 a	176,93 a	177,20 a	176,76 a
4	139,00 d	173,00 a	176,07 a	162,69 b
8	121,33 e	157,67 bc	164,67 b	147,89 c
12	120,67 e	153,33 c	162,00 b	145,33 c
Means	139,28 c	165,23 b	169,98 a	
*(3,88), **(4,48), *** (7,75)				
VL V (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	177,60 a	178,13 a	178,00 a	177,91 a
4	153,33 e	173,27 ab	174,93 ab	167,18 b
8	146,33 f	163,33 cd	169,67 bc	159,78 c
12	141,00 f	156,67 de	162,33 d	153,33 d
Means	154,57 b	167,85 a	171,23 a	
*(3,45), **(3,98), *** (6,89)				

*LSD_{0,05}T, **LSD_{0,05} VL, ***LSD_{0,05}T x VL. Mean values followed by same small letters do not differ significantly according to LSD test ($p < 0.05$). SP: Storage period, VL: Vase life, T: Treatment. 'NS' no significant. A) Control group subjected to tap water uptaking, B) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) after storage and C) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) before storage.

Chlorophyll-Total Amount in Leaf and Individual Sugar Glucose Amount in Petal

It was observed that total chlorophyll content in 'Magnum' cut roses was relatively low during storage, showing fluctuations with an overall increasing tendency. In this context, total chlorophyll values in treatments B and C were similar to each other, whereas both were higher than those recorded in treatment A (Table 11). Across the I, II, III, IV, and V vase life stages, total chlorophyll content generally decreased, although fluctuations were observed throughout the evaluation period. In particular, during the II and V vase life stages, chlorophyll values in treatments B and C were comparable, while both treatments exhibited higher values than treatment A (Table 11).

Significant differences in chlorophyll content were observed during both storage and vase-life periods in 'Magnum' cut roses. Previous studies have also reported that post-harvest treatments can significantly influence chlorophyll retention in cut roses. For instance, applications of 5% sucrose + 200 mg L⁻¹ HQC + 25 mg L⁻¹ STS + 350 mg L⁻¹ CoCl₂·6H₂O in 'Black Magic' cut roses; treatments with 200 ppm 8-HQS alone or in combination with sucrose in 'Taif' cut roses; applications of Zamzam water and its different concentrations in 'Top Secret' cut roses; and treatments with 250 mg L⁻¹ essential oils combined with 2% sucrose in 'Velvet' cut roses have all been reported to affect chlorophyll content (Wu et al., 2007; Elgimabi and Sliai, 2013; Hegazy and Ibrahim, 2019; Pouya et al., 2019).

Table 11
Changes in Chlorophyll-Total amounts during storage and at five different vase life stages in 'Magnum' cut roses

SP (days)	Treatment			Means
	A	B	C	
0	38,81 ef	38,81 ef	38,81 ef	38,81 c
7	38,36 ef	51,18 a	40,83 de	43,46 b
14	45,13 b-d	45,40 b-d	49,06 ab	46,53 a
21	41,96 c-e	41,03 c-e	45,98 bc	42,99 b
28	38,00 ef	33,72 f	28,46 g	33,39 d
Means	40,45	42,03	40,63	
LSD _{0,05} T: NS, LSD _{0,05} SP: 2,97, LSD _{0,05} T x SP: 5,14				
VL I (days)	Treatment			Means
	A	B	C	
0	38,81 cd	38,81 cd	38,81 cd	38,81 b
4	43,79 a	38,66 cd	36,61 d	39,69 ab
8	43,32 a	43,32 a	37,37 cd	41,34 a
12	42,80 ab	40,17 bc	32,85 e	38,61 b
Means	42,18 a	40,24 b	36,41 c	
*(1,43), **(1,66), *** (2,87)				
VL II (days)	Treatment			Means
	A	B	C	
0	38,36 d	51,18 ab	40,83 cd	43,46 b
4	46,46 ab	45,91 bc	49,34 ab	47,23 a
8	45,89 bc	48,93 ab	51,67 ab	48,83 a
12	40,63 cd	50,20 ab	48,62 ab	46,48 ab
Means	42,84 b	49,05 a	47,61 a	
*(2,67), **(3,09), *** (5,34)				
VL III (days)	Treatment			Means
	A	B	C	
*(NS), ** (3,85), *** (6,67)				

SP (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	45,13 b-d	45,40 b-d	49,06 a	46,53
4	48,15 ab	43,24 de	49,66 a	47,02
8	47,11 a-c	40,47 e	49,08 a	45,55
12	47,10 a-c	44,89 cd	41,59 e	44,53
Means	46,87 a	43,50 b	47,35 a	
*(1,62), **(NS), *** (3,25)				
VL IV (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	41,96 fg	41,03 g	45,98 de	42,99 d
4	55,93 a	50,17 bc	46,81 cd	50,97 a
8	51,01 b	47,01 cd	47,32 cd	48,45 b
12	43,01 e-g	44,78 d-f	51,04 b	46,28 c
Means	47,98 a	45,75 b	47,79 a	
*(1,78), **(2,06), *** (3,57)				
VL V (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	38,00 d-f	33,72 fg	28,46 g	33,39 c
4	40,45 c-e	35,00 e-g	42,51 b-d	39,32 b
8	41,33 a-c	45,91 a-c	47,77 ab	45,00 a
12	40,18 c-f	49,86 a	45,93 a-c	45,32 a
Means	39,99	41,12	41,17	
*(NS), ** (3,85), *** (6,67)				

*LSD_{0,05}T, **LSD_{0,05} VL, ***LSD_{0,05}T x VL. Mean values followed by same small letters do not differ significantly according to LSD test ($p < 0.05$). SP: Storage period, VL: Vase life, T: Treatment. 'NS' no significant. A) Control group subjected to tap water uptaking, B) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) after storage and C) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) before storage.

It was observed that individual sugar (glucose) content in 'Magnum' cut roses was relatively high during storage, showing fluctuations but an overall increasing trend. In this regard, glucose levels in treatments A and C were similar to each other, whereas both were higher than those recorded in treatment B (Table 12). Across the I, II, III, IV, and V vase life stages, individual sugar (glucose) content generally increased during vase life, although fluctuations were observed throughout the evaluation period. In this context, glucose levels in treatments A and C were comparable, while both treatments exhibited higher values than treatment B (Table 12).

Although individual glucose levels fluctuated during both storage and vase-life periods in 'Magnum' cut roses, an overall increase was observed in both experimental years. Previous studies have also demonstrated that post-harvest treatments and storage conditions can significantly influence sugar metabolism in cut roses. For example, sucrose and sucrose + 8-HQS applications in 'Sonia' cut roses, storage duration effects in 'Red Calypso', aluminum + ethanol +sucrose treatments in 'Red Sky' and 'Blizzard' cut roses, and MeJA combined with 2% sucrose solutions have all been reported to affect carbohydrate metabolism. In addition, increased pH levels in vase solutions have been shown to influence vase-life physiology in 'Tereasa' cut roses, while total soluble solids were differentially affected by sucrose-containing preservative solutions in 'Peach' and 'Sorbit' cut roses (Ichimura et al., 2003; Bayleyegn et al., 2012; Gebremedhin et al., 2013; Foukaraki et al., 2017; Shanan, 2017; Rooholla and Mehdi, 2018).

Table 12
Changes in sugar-glucose amounts during storage and at
five different vase life stages in 'Magnum' cut roses

SP (days)	Treatment			Means
	A	B	C	
0	0,92	0,92	0,92	0,92 b
7	1,03	1,06	1,18	1,09 a
14	1,08	0,98	1,16	1,07 a
21	1,04	1,08	1,15	1,09 a
28	1,01	1,03	1,19	1,07 a
Means	1,02 b	1,01 b	1,12 a	
LSD _{0,05} T: 0,05, LSD _{0,05} SP: 0,06, LSD _{0,05} T x SP: NS				
VL I (days)	Treatment			Means
	A	B	C	
0	0,92 a-c	0,92 a-c	0,92 a-c	0,92 a
4	0,83 de	0,85 cd	0,94 ab	0,88 ab
8	0,86 b-d	0,78 d-f	0,83 de	0,82 c
12	0,99 a	0,74 f	0,76 ef	0,83 bc
Means	0,90 a	0,82 b	0,86 ab	
*(0,04), **(0,05), ***(0,08)				
VL II (days)	Treatment			Means
	A	B	C	
0	1,03 b-d	1,06 b	1,18 a	1,09 a
4	0,87 fg	0,93 ef	0,96 c-f	0,92 c
8	1,02 b-e	0,99 b-e	1,02 b-e	1,01 b
12	1,04 bc	0,83 g	0,94 d-f	0,94 c
Means	0,99 ab	0,95 b	1,02 a	
*(0,05), **(0,05), ***(0,09)				
VL III (days)	Treatment			Means
*(0,05), **(0,06), ***(NS)				

SP (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	1,08 ab	0,98 cd	1,16 a	1,07 a
4	1,03 bc	0,91 d	0,96 cd	0,97 c
8	1,02 bc	0,98 cd	0,99 c	1,00 bc
12	1,01 c	0,98 cd	1,13 a	1,04 ab
Means	1,04 a	0,96 b	1,06 a	
*(0,04), **(0,04), *** (0,07)				
VL IV (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	1,04	1,08	1,15	1,09 a
4	0,98	0,96	0,99	0,98 b
8	1,03	0,97	0,98	0,99 b
12	1,12	1,03	1,14	1,10 a
Means	1,04 ab	1,01 b	1,07 a	
*(0,04), **(0,05), *** (NS)				
VL V (days)	Treatment			Means
	A	B	C	
	A	B	C	
0	1,01	1,03	1,19	1,07 a
4	0,92	0,92	0,98	0,94 c
8	1,03	0,9	0,97	0,97 bc
12	1,06	1,01	1,02	1,03 ab
Means	1,00 ab	0,96 b	1,04 a	
*(0,05), **(0,06), *** (NS)				

*LSD_{0,05}T, **LSD_{0,05} VL, ***LSD_{0,05}T x VL. Mean values followed by same small letters do not differ significantly according to LSD test ($p < 0.05$). SP: Storage period, VL: Vase life, T: Treatment. 'NS' no significant. A) Control group subjected to tap water uptaking, B) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) after storage and C) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) before storage.

Vase Life

In 'Magnum' cut roses, vase life was evaluated at five different postharvest intervals both before and after storage, starting from the first day the cut flowers were placed in vase solutions. During the vase-life assessment, senescence symptoms such as fading, petal browning, and discoloration were observed. Within the 12-day evaluation period, visual quality loss occurred at different rates depending on the vase-life stage. In unstored flowers, acceptable visual quality was maintained for approximately 8–12 days, whereas in stored flowers, quality declined progressively on a daily basis. When the five vase-life stages were ranked from highest to lowest performance, the order was: I > II > III > IV > V vase life. Overall, vase life duration and visual quality retention were longer in treatments B and C compared with treatment A. In general, vase-life duration in 'Magnum' cut roses decreased over storage periods; however, 7% sucrose application before and after storage had a positive effect on extending vase life.

Numerous studies have similarly demonstrated the effectiveness of various post-harvest treatments in extending vase life in cut roses. For instance, sucrose treatments (2% and 4%) in 'Baccara', ABA application in pH 6 solutions in 'Baccara', 200 ppm HQC + 3% sucrose in 'First Red', sucrose + $\text{Al}_2(\text{SO}_4)_3$ in 'Rote Rose', 30 ppm AgNO_3 + 3% sucrose in cut roses, sucrose combined with STS, citric acid, and $\text{Al}_2(\text{SO}_4)_3$ in 'Sena', 'Creamly', and 'Bouing', 25 ppm STS + 7.5% sucrose in 'Cardinal', 8-HQS (200 ppm) + 7% sucrose in 'Taif', aluminum + ethanol + sucrose preservative solutions in 'Red Sky' and 'Blizzard', 5% sucrose + 60 ppm $\text{Al}_2(\text{SO}_4)_3$ in cut roses, NG (75 and 125 mg L⁻¹) with or without 2% sucrose in 'High & Magic', 8-HQS combined with glucose, distilled water + 6% sucrose in Dutch hybrid roses, 1-MCP applications in 'First Red', and combinations of 5% sucrose + 200 ppm 8-HQS + 300 ppm salicylic acid in 'Top Secret' have all been reported to significantly improve vase life (Pompodakis and Joyce, 2003; Pompodakis et al., 2004; Jain et al., 2007; Ichimura and Shimizu-Yumoto, 2007; Elgimabi, 2011; Rezvanypour and Osfoori, 2011; Hayat et al., 2012; Elgimabi and Sliai, 2013; Gebremedhin et al., 2013; Bajwa et al., 2016; AleKasir et al., 2017; Sudaria et al., 2017; Chaudhary and Khanal, 2018; Demircioğlu et al., 2018; Kinfé et al., 2018).

CONCLUSION

As a result, storage duration and vase life in 'Magnum' cut roses were found to differ across a range of evaluated parameters, including relative fresh weight, solution uptake, pH variation in vase solution, electrical conductivity changes, relative water content, respiratory rate, ethylene production, leaf color, petal color, visual quality, flower opening, neck bending, leaf chlorophyll content, petal carbohydrate content, and overall vase life. It was determined that 'Magnum' cut roses can be successfully maintained under wet storage conditions for up to 21 days at 4°C and 70–75% relative humidity. Furthermore, a 7% sucrose pulsing treatment applied immediately after harvest was found to be effective for this cultivar. In addition, the application of 7% sucrose after storage also had a positive effect on extending vase life in this cut rose cultivar.

Declarations

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Conflict of interest

The author declare that there are no conflicts of interest regarding the publication of this manuscript.

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Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

AI declaration

The author did not use generative AI or AI-assisted technologies in the preparation of this manuscript.

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Figures



Figure 1

Weekly observations (weeks 1, 2, 3, and 4) of poststorage treatments on ‘Magnum’ cut roses (original photographs). A) Control group subjected to tap water uptaking, B) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) after storage and C) The group subjected to 7% sucrose water uptaking (with sodium hypochlorite and low pH) before storage.



Figure 2

Visual quality of ‘Magnum’ cut roses at the end of vase life (original photograph).



Figure 3

Flower opening (a) and neck bending (b) in ‘Magnum’ cut roses during storage or vase life (original photographs).