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Effect of Some Post-Harvest Pre-Treatments on Vase Life and Some Quality Parameters of Cut Rose Flowers

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ABSTRACT

Cut flowers are at risk of spoilage during transportation from the producer to the consumer after harvest. In cut flowers, both pre-harvest conditions and conditions during and after transportation significantly affect the post-harvest life, flower quality, and the aesthetic appearance of flowers. This study aimed to determine the effects of some pre-treatments on the post-harvest durability of cut rose (*Rosa hybrida* L.) flowers on vase life and some quality parameters. Seven different postharvest pretreatments [8-hydroxyquinoline 8-hydroxyquinoline+citric acid, 8-hydroxyquinoline+salicylic acid, 8-hydroxyquinoline+aluminum sulfate, 8-hydroxyquinoline+glycolic acid, 8-hydroxyquinoline+succinic acid, silver thiosulfate and sodium hypochlorite (NaOCl)] were used in the study, and the results were compared with the control (distilled water). The harvested flowers were kept in pre-treatment solutions for 6 hours at room temperature and then in cold storage (2-4°C) for 12 hours. After pre-treatment, the flowers were placed in glass vases containing 750 ml of distilled water each. The vase life, daily and total water uptake, relative fresh weight and full opening time of the flowers were measured in the experiment. In addition, a visual quality assessment of flowers was performed on the 8th day of the vase's life. The longest vase life among the treatments was obtained from silver thiosulfate treatment at 19.78 days, followed by control (distilled water) at 14.22 days and sodium hypochlorite at 13.33 days. The vase life of flowers in other treatments varied from 9.11 to 10.11 days. In conclusion, the silver thiosulfate (2 ml.L^{-1}) pretreatment was found to extend the vase life of flowers and positively affect other quality parameters.

Keywords: Cut rose, *Rosa hybrida*, pretreatment, vase life, silver thiosulfate, 8-HQ

Hasat Sonrası Bazı Ön Uygulamaların Kesme Gül Çiçeklerinin Vazo Ömrü ve Bazı Kalite Parametrelerine Etkisi

ÖZ

Kesme çiçekler, hasat sonrasında üreticiden tüketiciye kadar geçen sürede bozulma riski taşımaktadır. Kesme çiçeklerde gerek hasat öncesi koşullar gerekse taşıma sırasındaki ve sonrasındaki koşullar çiçeklerin estetik özelliklerinin yanında hasat sonrası ömrünü ve çiçek kalitesini önemli ölçüde etkilemektedir. Bu çalışmada, kesme gül (*Rosa hybrida* L.) çiçeklerinin hasat sonrası dayanımı üzerine bazı ön uygulamaların çiçeklerin vazo ömrü ve bazı kalite parametreleri üzerine etkilerinin belirlemesi amaçlanmıştır. Yedi farklı hasat sonrası ön uygulamanın [8-hidroksikinolin+sitrik asit, 8-hidroksikinolin+salisilik asit, 8-hidroksikinolin+alüminyum sülfat, 8-hidroksikinolin+glikolik asit, 8-hidroksikinolin+süksinik asit, gümüş tiyosülfat ve sodyum hipoklorit (NaOCl)] kullanıldığı çalışmada, sonuçlar kontrol (saf su) ile karşılaştırılmıştır. Hasat edilen çiçekler oda sıcaklığında 6 saat ön uygulama solüsyonlarında bekletildikten sonra, 2-4°C sıcaklıktaki soğuk hava deposunda 12 saat süre ile ön uygulama solüsyonlarında bekletilmiştir. Çiçekler daha sonra içinde saf su (750 ml) bulunan cam vazolara konulmuştur. Araştırmada; çiçeklerin vazo ömrü, günlük su tüketimi ve toplam su tüketimi, oransal taze ağırlık değişimi ve çiçeklerin tam açılma süreleri ölçülmüştür. Ayrıca çiçeklerin görsel kalitelerini belirlemek amacıyla vazo ömrünün 8. gününde görsel kalite değerlendirmesi yapılmıştır. Uygulamalara göre en uzun vazo ömrü gümüş tiyosülfat uygulamasında (19.78 gün) elde edilirken, bunu kontrol (14.22 gün) ve NaOCl (13.33 gün) uygulamaları ile izlemiştir. Diğer uygulamalardaki çiçeklerin vazo ömürleri 9.11-10.11 gün arasında değişmiştir. Sonuç olarak, gümüş tiyosülfat (2 ml.L^{-1}) ön uygulamasının çiçeklerin vazo ömrünü artırması yanında incelenen diğer kalite parametreleri üzerine de olumlu etki yaptığı saptanmıştır.

Anahtar Kelimeler: Kesme gül, *Rosa hybrida*, ön uygulama, vazo ömrü, gümüş tiyosülfat, 8-HQ

INTRODUCTION

A rose, one of the world's most traded ornamental plant species, is used in many fields, such as the ornamental plants sector, cosmetics, health, food and tourism. Roses are used in the ornamental plants sector as cut flowers and indoor and outdoor ornamental plants. Cut flowers often deteriorate due

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to various factors, from when they are harvested until they reach the final consumer. Although cut flowers vary according to species and varieties, 25-50% of those produced in our country are lost during storage and transportation. Reducing the loss of cut flowers has great importance for domestic and foreign marketing [1, 2]. Post-harvest resistance of cut flowers is influenced by pre-harvest (genetic factors, environmental conditions, plant nutrition practices, etc.), during harvest (harvest time, cutting location, cutting technique etc.) and post-harvest factors (bundling, re-cutting, water extraction, pre-cooling, storage and transportation etc.) [2, 3, 4, 5]. While the effect of pre-harvest factors on vase life was reported as 2/3, the effect of post-harvest factors on vase life was noted as 1/3.

One of the most important quality parameters in cut flowers is vase life, and the term vase life refers to the time from the placement of cut flowers in the vase solution until the loss of their visual value. The long vase life of cut flowers affects not only consumers but also the trade [6]. It is known that post-harvest treatments can extend the vase life of cut flowers. Flower preservative solutions have been made mandatory in many countries that trade in cut flowers. These solutions usually contain germicides (bactericides and fungicides), surfactants, acidifiers, ethylene inhibitors and sugars.

The main bactericides used in cut flowers to control bacteria and other microorganisms in vase water and to prolong the vase life of flowers are 8-hydroxyquinoline sulfate (8-HQS), 8-hydroxyquinoline citrate (8-HQC), silver nitrate ($AgNO_3$), silver thiosulfate ($Ag_2S_2O_3$) and aluminum sulfate $Al_2(SO_4)_3$ [7, 8, 9]. The most commonly used compounds are silver nitrate, silver thiosulfate and 8-hydroxyquinoline citrate. In post-harvest water uptake of cut flowers, it is desirable for the pH value of the water or solution to be low [10]. It has been reported that 8-hydroxyquinoline is generally used to prevent fungal and bacterial growth in vase solution for cut flowers [11, 12, 13, 14]. Succinic acid has been reported to avoid the decline in chlorophyll content and, consequently, photosynthesis, which is an effect of cellular aging, as well as to increase the strength of the cell wall [15, 16, 17]. Citric acid has been reported to eliminate microorganisms formed in vase solution, increase water conductivity by reducing vascular bundle blockage and prolonging vase life [17, 18]. Aluminum sulfate has been found to lower the pH in the petals of cut rose flowers, reduce anthocyanin loss, and improve flower quality. [19]. Thwala et al. [20] reported that glycolic acid was used to lower the pH of the vase solution. Silver thiosulfate has been stated to be an effective biocide and is widely used to inhibit the synthesis of ethylene and its effects [21].

With the development and use of suitable vase solutions for cut flower species, post-harvest quality, product losses and, therefore, economic losses can be reduced, consumer satisfaction can be increased with long-lasting flowers, and the use of vase solutions in cut flowers can be expanded in our country. In this study, the goal was to ascertain how certain post-harvest pre-treatments affected the cut roses' vase life and quality parameters.

MATERIAL METHOD

Experimental Site and Plant Material

The research was conducted at Ankara University, Faculty of Agriculture, Department of Horticulture, between May and September (2021). The plant material used in the study was the red-colored, standard-type 'Samourai' cut rose variety of the *Rosa hybrida* L. species. According to the breeder company's catalog data, the vase life of the 'Samourai' variety is reported to range between 10 and 12 days [22].

Method

•Preparation of post-harvest pre-application solutions: In the study, 8-hydroxyquinoline + aluminum sulfate, 8-hydroxyquinoline + citric acid, 8-hydroxyquinoline + succinic acid, 8-hydroxyquinoline + salicylic acid, 8-hydroxyquinoline + glycolic acid, silver thiosulfate, sodium hypochlorite (NaOCl) and distilled water as control were used as postharvest pretreatment solutions. Aluminum sulfate [($Al_2(SO_4)_3$)], citric acid (CA), salicylic acid (SA), glycolic acid (GA) and succinic acid (SUA) were added to each of the solutions using 8-HQ as acidulants. Vita STS containing silver thiosulfate was used as a commercial control. The recommended commercial dosage for this product is 1-3 ml.L^{-1}. Sodium hypochlorite containing 15.75% active chlorine was also used in the study. Doses of the compounds used in the study and pH values of the solutions are given in Table 1.

Table 1. Post-harvest pre-treatment solutions and pH values

Treatments	pH of the solution
Distilled water (control)	6.61
Silver thiosulfate	8.15
Sodium hypochlorite (NaOCl)	10.54
8-HQ (300 mg/L) + Aluminum sulfate (77.1 mg/L)	5.04
8-HQ (300 mg/L) + Citric acid (100 mg/L)	5.06
8-HQ (300 mg/L) + Salicylic acid (130 mg/L)	5.05
8-HQ (300 mg/L) + Glycolic acid (45 µL)	4.95
8-HQ (300 mg/L) + Succinic acid (100.4 mg/L)	4.91

•Harvesting flowers: Cut rose flowers were harvested early in the morning (08.30-10.00 a.m.) at commercial harvest maturity (when petals start to curl backward) [23]. On May 6, 2021, from the greenhouse of a commercial cut rose production company in Antalya (Figure 1).

•Post-harvest pre-treatments and determination of vase life of flowers: Flowers harvested at a length of 70 cm in the greenhouse and brought to the processing house (Antalya) were first kept in pretreatment solutions for 6 hours under room conditions. The flowers in the control treatment were kept only in pure water. After 6 hours, the flowers removed from the pretreatment solutions were packaged and placed in perforated cardboard boxes and transported to the laboratory (Ankara) by road within 10 hours. The bases of the flowers brought to the laboratory were cut obliquely at a length of 2.5 cm, placed in re-prepared post-harvest pretreatment solutions, and kept in cold storage (2-4°C temperature and 95% humidity) for 12 hours (Figure 2). After 12 hours, the stems of the flowers removed from the pretreatment solutions were cut obliquely at a length of 50 cm and placed in 1 L glass vases (6 flowers per vase) containing 750 ml of distilled water, and their vase life was determined (Figure 3). The leaves remaining in the vase solution from the basal parts of the flower stems were manually plucked and removed.

•Conditions of the room for determining the life of the vase: The vase life of the flowers was determined in a vase life chamber with 21±20°C temperature, 65±5% relative humidity, 1000 lux light and 12 hours day length conditions [23, 24, 25, 26].

Figure 1. Harvesting of cut rose flowers and view from harvest form

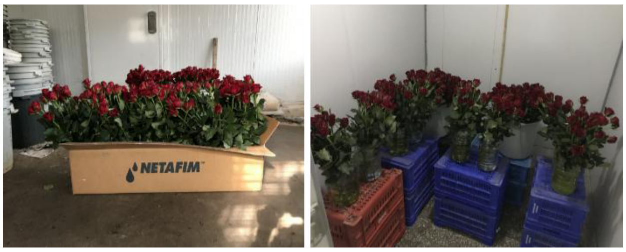


Figure 2. Flowers held in post-harvest pre-treatment solutions under room conditions (left) and cold storage (right)

Figure 3. View of flowers placed in glass vases with distilled water in the vase life determination room

Traits Examined in the Experiment

•Vase life (day): The vase life of cut rose flowers were accepted as the number of days from the day the flowers were placed in the vase until the day the petals started to fade, and the flower necks started to bend [25, 27].

•Relative fresh weight (RFW) (%): The branch weights of the flowers were calculated daily by measuring the difference between the weights of vases with flowers and those without flowers, using a digital balance with a sensitivity of 0.01 gram. Relative fresh weight measurements were made at 2-day intervals during the vase life, and the following formula was used to calculate the relative fresh weight [28].

$$RFW\ (\%) = (Wt/Wt_{-0}) \times 100$$

Wt: is the stem weight (g) at t=$day_{1,2,3}$ etc.

Wt_{-0}: is the same stem weight at t=day_0

•Daily solution uptake (DSU): Daily vase solution uptake was every 2 days during the vase lifetime. The amount of solution received by the flowers every 2 days during the vase life of the flowers was calculated with the help of a precision scale sensitive to 0.01 gram using the following formula [25, 28]. Daily vase solution uptake values are given in grams, with an average of 6 flowers used in 3 replicates.

$$DSU = St_{-1} - St$$

DSU: Daily vase solution uptake

St_{-1}=is the weight of vase solution (g) on the previous day

St=is the weight of vase solution (g) at t=$days_{1,2,3}$ etc.,

The weights of the vases were documented before inserting the flowers. After placing the flowers, the combined weight of the vase and vase solution was measured. Additionally, during the vase's lifespan, the flowers were removed from the vases every two days, and the combined weight of the vase and vase solution was recorded again before weighing.

•Total vase solution uptake (g): The total vase solution uptake by the flowers during their vase life was calculated by subtracting the amount of water evaporated from flowerless vases. Total vase solution uptake is expressed as the average (g) of 6 flowers per replicate.

•***Visual quality:*** Visual quality was evaluated on a scale of 1-5 (1: very bad, 2: bad, 3: medium, 4: good, 5: very good), taking into account the fading, blackening, bluing, curling backward, drying and shedding of the petals of all flowers, opening and neck bending of the flowers, and yellowing, drying and shedding of the leaves. A visual quality assessment was performed on the 8th day of the flowers' vase life.

•***Full bloom time of flowers:*** The opening time of flowers was evaluated on a scale of 1-3 (1: closed, 2: half open, 3: fully open) (Figure 4).

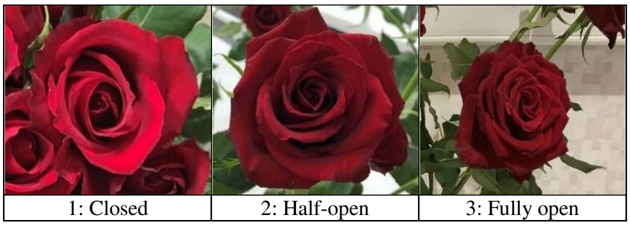


Figure 4. Stages for flower opening time

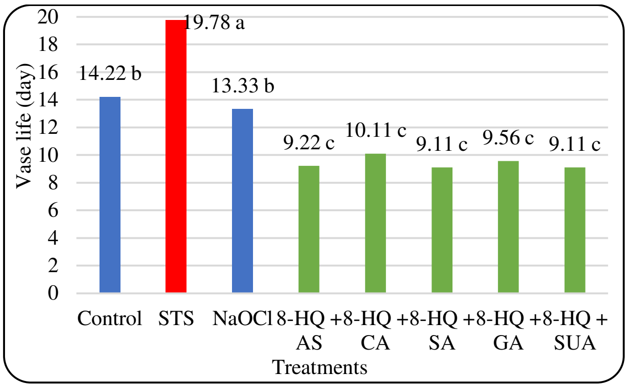
Evaluation of Data and Statistical Analysis

The study was conducted using the Randomized Plot Experimental Design (RPD) with 3 replications involving 144 flowers, with 6 flowers in each replicate. The SAS statistical software package was used to analyze the obtained data. Differences between means were evaluated using the Duncan Multiple Comparison Test. In addition, correlations were examined between daily vase solution uptake and vase life, total vase solution uptake and vase life, and relative fresh weight and vase life.

RESULTS AND DISCUSSION

Effect of Postharvest Pre-treatments on Vase Life of Flowers

The results of various pre-treatments applied after harvest on the vase life of cut rose flowers are presented in Figure 5. The results from various pre-harvest and post-harvest treatment solutions on the vase life of flowers were statistically significant. Among the treatments, the silver thiosulfate treatment produced the longest vase life with 19.78 days, followed by control (distilled water) treatment with 14.22 days and sodium hypochlorite with 13.33 days. The difference between the control and sodium hypochlorite treatments was statistically insignificant. It was determined that the vase life of flowers in solutions containing 8-HQ and different acidifiers varied between 9.11 and 10.11 days, and the differences between these treatments were statistically insignificant.



*The means displayed with the same letter and color do not differ at the 5% significance level. (STS:Silver thiosulfate, NaOCl:Sodium hypochlorite, 8-HQ + AS:8-hydroxyquinoline+aluminum sulfate, 8-HQ + CA:8-hydroxyquinoline + citric acid, 8-HQ + SA:8-hydroxyquinoline + salicylic acid, 8-HQ + GA:8-hydroxyquinoline +glycolic acid, 8-HQ + SUA:8-hydroxyquinoline + succinic acid)

Figure 5. Effects of treatments on vase life of flowers

The sensitivity of cut roses to ethylene varies depending on the varieties. Many cuts rose cultivars are moderately sensitive to ethylene [29], while some cultivars (especially the fragrant ones) are highly sensitive to ethylene. Silver thiosulfate is both a fungicide and bactericide (germicide) and an ethylene inhibitor [21]. The ethylene sensitivity of the 'Samourai' variety used in our study is unknown; however, according to the catalog data of the breeder company (Meilland), the vase life of the variety is reported to be 10-12 days. In our study, the vase life of the 'Samourai' cultivar varied between 19.78 days and 9.11 days. The identification of flowers with the longest vase life in the silver thiosulfate treatment is thought to be due to the dual properties of silver thiosulfate as both an anti-ethylene agent and a germicide. Similarly, it has been reported that silver thiosulfate inhibits the effects of aging by inhibiting ethylene and ethylene receptors and increases the vase life of flowers in many cut flower species, especially cut roses [21, 30, 31, 32, 33, 34].

The primary factor limiting the vase life of cut roses is the blockage of vascular bundles by fungi and bacteria in the vase solution, which leads to neck bending (Figure 6). 8-HQ is widely used alone (50-300 mg.L^{-1}) and combined with other compounds to prevent fungal and bacterial growth in cut flowers, post-harvest pre-treatments and vase solutions [11, 12, 13, 14]. In our study, 8-HQ (300 mg.L^{-1}) was used not alone but in combination with different acidifiers. Our results determined that the solutions containing 8-HQ had shorter vase life values than the control and sodium hypochlorite treatments. In all solutions containing 8-HQ, burning and blackening were observed at the base of the stem and on the parts of the branch that remained in water in the vase. In the later days of the vase life, this burning and blackening progressed towards the upper part of the branch (Figure 7). The short vase life in solutions containing 8-HQ may be due to the high dose of 8-HQ and its stronger effect with other acidifiers. Van Doorn et al. [9] reported that solutions containing 8-HQ in combination with 8-HQ and acidifiers had a toxic impact and reduced the vase life of flowers. In addition, Alaey et al. [43] reported that a 200 $mg.L^{-1}$ dose of salicylic acid was toxic in cut *lisianthus* flowers. In our study, the vase life of flowers in 8-HQ treatment containing glycolic acid was shorter than the control. Turbidity was observed in the vase solution containing glycolic acid, likely due to the high concentration of compounds in the solution, which stimulated microbial activity and caused burning at the base of the stem and bark. Kinnersley [35] and Kazaz et al. [36] stated that glycolic acid promotes microbial activity in vase solutions, clogs vascular bundles, reduces vase solution uptake and causes deterioration of turgor. As turgor deteriorates, twisting of the stems or necks of cut flowers occurs, ultimately ending their vase life [7, 37, 38].


Figure 6. Neck bending

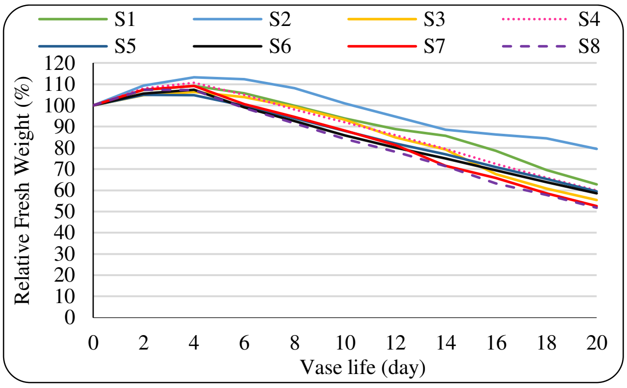

Figure 7. Burning and blackening of flower stem

In our study, the vase life of flowers treated with sodium hypochlorite, commonly known as bleach, was in the same statistical group as those in the control group. Sodium hypochlorite is also known as a good disinfectant. The active chlorine in sodium hypochlorite is thought to reduce or prevent microbial activity in the vase solution. Similarly, many studies have reported that sodium hypochlorite increases both vase solution uptake and vase life by avoiding or reducing the formation of fungi and bacteria both in the vase solution and at the base of the stems of flowers, both in cut roses and in many cut flower species [9, 39, 40, 41].

Tuna [42] reported that the vase life of cut roses varied between 8.0 days and 16.50 days in solutions containing different essential oils and 8-HQ. In our study, the vase life of cut roses varied between 9.11 days and 19.78 days. Although the data obtained in our study are generally similar to that of Tuna [42], the lower and upper limit values differ. This situation is thought to be caused by factors such as vase solutions, cultivars, growing conditions of the flowers, and related factors.

Relative Fresh Weight

The effects of different post-harvest pre-treatments on the relative fresh weight of cut rose flowers are shown in Figure 8. The impact of pre-treatment on changes in the relative fresh weight of cut rose flowers was statistically significant. On the 2nd and 4th days of vase life, differences in relative fresh weight among the treatments were statistically insignificant. On the 2nd day of the study, the relative fresh weights among the treatments ranged from 104.84% and 109.34%, while on the 4th day, they ranged from 104.87% and 113.23%. On the 6th, 8th, 10th, 12th, 14th, 16th, 18th, and 20th days of vase life, differences in relative fresh weight among the treatments were statistically significant.



S1:Distilled water (control), S2:Silver thiosulfate, S3:Sodium hypochlorite, S4:8-HQ+Aluminum sulfate, S5:8-HQ+citric acid, S6:8-HQ+salicylic acid, S7:8-HQ+glycolic acid, S8:8-HQ+succinic acid)

Figure 8. Effects of applications on relative fresh weight of flowers during vase life

The silver thiosulfate treatment found the highest relative fresh weight increase between the 6th and 20th days of vase life. Starting from the 4th day onward, the relative fresh weights gradually decreased and by the 20th day compared to the 4th day, they showed a reduction of 41.42% in the control (distilled water), 27.26% in the silver thiosulfate treatment, 47.17% in the sodium hypochlorite treatment, 44.59% in the 8-HQ + aluminum sulfate treatment, 43.32% in the 8-HQ + citric acid treatment, 44.56% in the 8-HQ + salicylic acid treatment, 51.01% in the 8-HQ + glycolic acid treatment, and 51.76% in the 8-HQ + succinic acid treatment. Relative fresh weights ranged between 98.82% and 12.39% on day 6, 91.60% and 108.20% on day 8, 84.12% and 100.87% on day 10, 78.20% and 94.71% on day 12, 71.35% and 88.62% on day 14, 63.26% and 86.37% on day 16, 57.75% and 84.56% on day 18, 51.81% and 79.53% on day 20. The lowest relative fresh weights were observed in the 8-HQ combined with succinic acid treatment during the 6th to 20th days of vase life.

In our study, it was determined that the relative fresh weight increases increased until the 4th day of vase life. It has been reported that the relative fresh weight increases in cut roses in vase solutions can continue for up to 7-8 days and then decrease [42, 43]. Ichimura et al. [27] reported that the relative fresh weight increases in cut roses increased between the first 3-9th days and started to decline after the 9th day, and Ichimura et al. [27] reported that the relative fresh weights in cut roses increased until the 3rd day in the control and until the 6th day in different flower preservatives. Although the results obtained in our study are generally consistent with the earlier literature, differences were observed in the days of relative fresh weight gain. These differences are likely attributed to factors such as the solution used, plant variety, harvest method, and experimental conditions. Some studies reported that the relative fresh weight increase in cut roses could continue until the 7th-9th days of vase life and decrease in the following days. Similarly, Tuna [42] reported that the relative fresh weight of cut roses increased at the beginning of the vase life and decreased in the following days.

Daily Vase Solution Uptake

The effects of different postharvest pretreatments on daily vase solution uptake of cut rose flowers are presented in Table 2. It was determined that the pretreatment solutions had a statistically significant effect on the daily vase solution uptake of flowers. In all solutions, vase solution uptake ranged from 69.74 g (silver thiosulfate) to 54.30 g (8-HQ + citric acid) at the end of the first 2 days of vase life, while it ranged from 71.98 g (silver thiosulfate) to 55.48 g (8-HQ + citric acid) at the end of the 4th day. From the 2nd to the 20th day of the vase life, the daily vase solution uptake of the flowers decreased by 68.44% in the control group. In comparison, it varied between 42.39% in silver thiosulfate treatment and 61.60% in sodium hypochlorite treatment between the same days. In solutions containing different acidifiers together with 8-HQ, the daily vase solution uptake of flowers decreased between 89.78% and 68.44% from the 2nd to the 20th day of vase life (Table 2).

Our study determined that daily vase solution uptake decreased from the 4th day in some treatments and the 6th day in some treatments. Ueyema and Ichimura [23], Ichimura et al. [27], He et al. [28] and Tuna [42] reported that the vase life of daily vase solution in cut roses increased in the first two days and then started to decrease.

Table 2. Effects of treatments on daily vase solution uptake of flowers

Treatment	Daily Uptake of Vase Solution (g/6 branches) (days)									
	2	4	6	8	10	12	14	16	18	20
Control	60.30 b	63.49 ab	65.41 ab	57.65 a	49.07 b	39.94 b	28.42 b	24.36 b	21.61 b	19.03 b
STS	69.74 a	71.98 a	69.02 a	64.99 a	62.90 a	60.72 a	56.45 a	52.75 a	47.38 a	40.18 a
NaOCl	54.59 b	61.27 ab	62.14 ac	50.83 ab	46.43 b	36.13 b	27.28 b	25.46 b	24.48 b	20.96 b
8-HQ + AS	55.12 b	57.99 b	50.86 bd	38.04 bc	25.59 c	15.96 c	12.33 c	10.75 c	8.49 c	6.93 c
8-HQ + CA	54.30 b	55.48 b	48.63 cd	33.01 c	25.53 c	19.26 c	14.09 c	11.91 c	9.34 c	8.20 c
8-HQ + SA	59.84 b	63.85 ab	53.67 bd	33.31 c	23.60 c	19.44 c	15.14 c	12.30 c	9.05 c	6.11 c
8-HQ + GA	58.05 b	60.65 b	51.65 bd	30.52 c	19.25 c	14.48 c	11.77 c	10.03 c	7.91 c	6.01 c
8-HQ + SUA	60.30 b	63.49 ab	65.41 ab	57.65 a	49.07 b	39.94 b	28.42 b	24.36 b	21.61 b	19.03 b

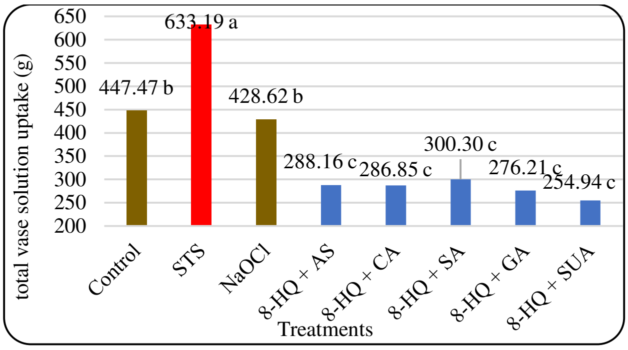
*STS:Silver thiosulfate, NaOCl:Sodium hypochlorite, 8-HQ+AS:8-hydroxyquinoline+aluminum sulfate, 8-HQ+CA:8-hydroxyquinoline+citric acid, 8-HQ+SA:8-hydroxyquinoline+salicylic acid, 8-HQ+GA:8-hydroxyquinoline+glycolic acid, 8-HQ+SUA:8-hydroxyquinoline+succinic acid

Total Vase Solution Uptake

Different postharvest pretreatments were found to influence the total vase solution uptake significantly. Among the treatments, silver thiosulfate treatment has the highest uptake of the entire vase solutions with 633.19 g, followed by control (distilled water) with 447.47 g and sodium hypochlorite with 428.62 g. The difference between the control and sodium hypochlorite treatment was statistically insignificant. Total vase solution uptake of the solutions containing 8-HQ and other acidifiers varied between 300.3-254.94 g, and the differences between these treatments were statistically negligible. Of all the treatments, the 8-HQ + succinic acid application has the lowest total vase solution intake, with 254.94 g.

Silver thiosulfate treatment, which had the highest total vase solution uptake, significantly increased total vase solution uptake with a value of 633.19 g compared to the control treatment. Sodium hypochlorite treatment followed the silver thiosulfate treatment with a value of 428.62 g/6 branches. No statistically significant differences were observed among the treatments of 8-HQ combined with aluminum sulfate, citric acid, salicylic acid, glycolic acid, and succinic acid; still, these treatments decreased vase solution uptake relative to the control group (Figure 9). Tuna [42] reported that total vase solution uptake in cut roses ranged from 31.83 g (8-HQ + sucrose) to 11.29 g (linalyl acetate) per branch.

Previous studies have reported that low vase solution uptake in cut flowers is due to blockage at the base of the flower stem and that one of the main reasons for blockage is microbial growth in the vase solution [28]. Although microbial activity in the vase solutions was not determined in our study, the fact that silver thiosulfate has germicidal properties and anti-ethylene properties is one of the main reasons for the highest total vase solution uptake. Though 8-HQ is also a good germicide, in our study, it caused toxic effects on flowers due to the high dose and the combination with other acidifiers. This resulted in a decrease in both daily and total vase solution uptake across all combinations containing 8-HQ. The gradual decline in vase solution uptake during the later days of vase life is likely due to increased bacterial populations in the vase solutions. This bacterial growth may have caused blockages at the base of the flower stems, reducing water uptake.



*The means displayed with the same letter and color do not differ at the 5% significance level. (STS:Silver thiosulfate, NaOCl:Sodium hypochlorite, 8-HQ + AS:8-hydroxyquinoline + aluminum sulfate, 8-HQ + CA:8-hydroxyquinoline+ citric acid, 8-HQ + SA:8-hydroxyquinoline + salicylic acid, 8-HQ + GA:8-hydroxyquinoline + glycolic acid, 8-HQ + SUA:8-hydroxyquinoline + succinic acid)

Figure 9. Effects of applications on total vase solution uptake

Visual Quality

One of the most important post-harvest quality parameters in cut flowers is the aesthetic appearance of the flowers, in other words, their visual quality. Visual quality is affected by both external and internal factors. In our study, the visual quality of flowers was assessed on the 8th day of the vase's life. This time was chosen because it represents the common point at which deterioration begins across all treatments.

The data on the visual quality scores of the flowers in our study are given in Table 3, and the images are shown in Figure 10. In the scale created to evaluate the visual quality of the flowers, it was determined that the flowers received between 3 and 5 quality points. Silver thiosulfate treatment received the highest visual quality score (5) among the treatments. In this treatment, it was observed that the flowers maintained their visual quality almost until the first day of the vase life. Flowers and leaves started to deform in all solutions containing 8-HQ and acidifiers (Figure 10).

Table 3. Visual quality scores of flowers according to treatments

Treatments	Visual Quality Score (1-5)
Distilled water (control)	4
Silver thiosulfate (STS)	5
Sodium hypochlorite (NaOCl)	4
8-Hydroxyquinoline+Aluminum sulfate (AS)	3
8-Hydroxyquinoline+Citric acid (CA)	3
8-Hydroxyquinoline+Salicylic acid (SA)	3
8-Hydroxyquinoline+Glycolic acid (GA)	3
8-Hydroxyquinoline+Succinic acid (SUA)	3

Figure 10. View of flowers scoring moderate (3 points) (a), good (4 points) (b) and very good (5 points) (c) on the visual quality scale

Figure 11. Color change in the petals of flowers (left) and a view of flowers that are bending their necks without flowering (right)

As of the 6th day of the study, some flowers of 8-HQ + glycolic acid, 8-HQ+SA, 8-HQ+CA, 8-HQ+AS and 8-HQ+SUA treatments started to bend their necks before full opening, and the formation of neck bending continued in the flowers of these treatments in the following days of the vase life (Figure 11).

•Full blooming time of flowers: In cut roses, the flowers are harvested when the petals curl backward (commercial harvest form). One of the biggest problems in cutting roses after harvesting is that the flowers bend their necks before fully opening in vase solutions. Both early opening and long-lasting flowers are among the most desired characteristics. In our study, the earliest full opening of the flowers was observed in 8-HQ + citric acid treatment on day 8.44 of the vase life, followed by the control treatment with 9.67 days. The difference between these two treatments was found to be statistically insignificant. Statistically significant differences were found between the treatments regarding flower opening time. Flowers opened later in the silver thiosulfate treatment (14.44 days), and their vase life was longer than the other treatments (Table 4).

In all solutions containing 8-HQ, some flowers were observed to bend their necks before fully opening. This may be due to the high dose of 8-HQ and its stronger effect with acidifiers.

Table 4. Full blooming time of flowers

Treatments	Full Blooming Time of Flowers (day)
Distilled water (control)	9.67 bc
Silver thiosulfate	14.44 a
Sodium hypochlorite (NaOCl)	11.33 b
8-Hydroxyquinoline+Aluminum sulfate	11.56 b
8-Hydroxyquinoline+Citric acid	8.44 c
8-Hydroxyquinoline+Salicylic acid	12.11 ab
8-Hydroxyquinoline+Glycolic acid	11.22 b
8-Hydroxyquinoline+Succinic acid	10.00 bc

Relationships Between Vase Life and Relative Fresh Weight and Between Vase Life and Daily and Total Vase Solution Uptake

Correlations were made to determine whether there was a relationship between the vase life of the flowers and relative fresh weight and daily and total vase solution uptake. According to the results obtained, a very high positive correlation was found between daily uptake, total vase solution uptake and relative fresh weight (r=0.91). This indicates that relative fresh weight increased as daily and total vase solution uptake increased. Furthermore, a high positive correlation was observed between daily and total vase solution uptake and vase life (r=0.99). In other words, vase life was determined to be prolonged with the increase in daily and total vase solution uptake. A very high positive correlation was determined between relative fresh weight and vase life (r=0.91). It was determined that the vase life was also prolonged as the relative fresh weight increased.

CONCLUSION

This study investigated the effects of 8 different postharvest pre-treatments on vase life and some quality parameters of 'Samourai' cut rose cultivar flowers. In the study, the longest vase life was 19.78 days in silver thiosulfate (STS) treatment. STS treatment increased the vase life by 53.54%. It was determined that the relative fresh weights increased until the first 4 days of the vase life and decreased gradually in the following days. Daily vase solution uptake increased until the first 4 days of vase life in some treatments and until the first 6 days of vase life in some treatments and gradually decreased in the following days. Very high positive correlations were found between daily and total vase solution intake and relative fresh weight, daily and total vase solution uptake and vase life, and relative fresh weight and vase life. A visual quality assessment was performed on the 8th day of the vase's life. Silver thiosulfate treatment received the highest visual quality score (5) among the treatments. On the 8th day of vase life, the flowers with the highest visual quality among the treatments were found in silver thiosulfate treatment. The flowers with the lowest visual quality were obtained from the solutions containing 8-HQ.

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