Comparison of the effects of different floral preservative solutions on extending the vase life of *Rosa hybrid* flowers

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ABSTRACT

This study was conducted to evaluate the effect of some flower preservation solutions and their interactions on the vase life of cut roses (*hybrid* × *Rosa* L.) using a completely randomized design with three replicates and five flowers per replicate. The solutions included the addition of sucrose at a concentration of (0 and 20) g L^{-1}, silver nitrate at a concentration of 40 and 80 mg L^{-1}, nano silver nitrate at a concentration of 5 and 10 mg L^{-1}, citric acid at a concentration of 200 and 400 mg/L, ethyl alcohol at a concentration of 10%, and lavender oil at a concentration of 2%. The results showed that sucrose had a significant effect on most of the evaluated postharvest traits, as it provided the necessary energy for metabolic activities, maintained osmotic balance, delayed flower senescence, and enhanced flower color, thereby extending vase life. The results also demonstrated that both nano-silver nitrate concentrations, as well as 10% ethyl alcohol and 2% lavender oil, recorded the best significant values in extending the vase life of roses, by suppressing microbial proliferation, preventing xylem vessel occlusion, and reducing ethylene biosynthesis, thereby improving water uptake and maintaining tissue integrity. Citric acid enhanced water uptake in cut flowers by acidifying the vase solution, which improved xylem conductivity and suppressed microbial proliferation. It was observed that the combination of sucrose and nano silver, as well as sucrose with ethyl alcohol and lavender oil, achieved the best values for most of the studied attributes. These results underscore the importance of selecting the optimal preservation solution, combining chemical and natural treatments, to achieve a longer vase life and support sustainable development in the flower industry.

Keywords: Citric acid; ethanol solution; Floral Preservatives; Lavender oil; Rose; Sucrose; Vase life

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INTRODUCTION

Flowers, with their beauty, are a reflection of the greatness of God's creation (1). They are not only aesthetic elements, but they also contribute to improving a person's psychological health, by reducing stress, raising mood, and creating a feeling of comfort and happiness. The red cultivar of hybrid roses, particularly Mister Lincoln within the species Rosa × hybrida, is considered one of the most important Hybrid Tea rose cultivars used in horticultural and ornamental studies. This cultivar is characterized by its large, dark red velvety flowers and its strong fragrance, which results from a high concentration of secondary aromatic compounds (2). It is also distinguished by its long and sturdy stems, making it suitable for commercial cutting and for experimental studies related to plant morphology and flower quality. Studies have shown that this cultivar exhibits good adaptability to a wide range of environmental conditions and responds clearly to pruning and fertilization practices (Guan et al., 2024), making it an appropriate model for investigating the effects of agricultural factors on the growth and productivity of ornamental plants. Furthermore, it is widely utilized in breeding programs aimed at improving genetic traits due to the stability of its morphological characteristics and its high aesthetic value (3). The production and post-harvest management of cut roses and ornamental flowers is a promising economic project in Iraq, especially in northern regions such as Nineveh, where suitable climatic conditions are available year-round, labor is available at reasonable prices, and a distinguished geographical location facilitates export operations (4). Flowers cultivated for commercial purposes are referred to as cut flowers, representing a significant economic sector in many countries, particularly those engaged in the production and export of ornamental plants. These flowers are widely used in floral arrangements, interior decoration, special events, and international trade, contributing substantially to economic revenue and serving as an important source of foreign currency (5). According to (6), the global cut flower market size was valued at USD 39.08 billion in 2024 and is expected to reach USD 51.83 billion by 2030 at a CAGR of 4.9%. Data indicates that roses account for approximately 32.57% of the total revenue in this market, making it one of the most sought-after flower types globally.

The vase life of cut flowers depends on the availability of water and nutrients, and is affected by factors such as natural ripening, nutrient deficiency, microbial attack, mechanical damage, stem vessel blockage, temperature fluctuations during storage and transportation, ethylene accumulation, as well as the type and variety of the plant (7).

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Recent studies have demonstrated the importance of adding sucrose to preservative solutions in extending the vase life of cut flowers. (8) demonstrated that combining sucrose with antimicrobial substances improved water absorption and reduced vascular obstruction, which was reflected in stem firmness and petal viability. (9) study demonstrated that a 500 mM sucrose solution delayed the loss of anthocyanin pigment in petals, thus slowing the senescence-related color fading. Together, these results indicate that sucrose is a key component in improving the quality and post-harvest shelf life of cut flowers. Citric acid helps reduce microbial growth, and the effectiveness of preservative solutions depends on the appropriate concentration and environmental conditions (10). (11) reported that placing rose stems in an acidic solution with a pH between 3 and 4 improves water uptake and prolongs vase life compared to solutions with a higher pH such as 5 or 7, the study also showed that immersing rose stems in a malic acid solution and then treating them with aluminum sulfate and citric acid for 24 hours improved the quality of the flowers and extended their lifespan in the vase Figure (1).

Figure 1: Floral structure of the rose flower (*Rosa × hybrida*).

Lavender oil contains phenolic and terpene compounds with antibacterial and antifungal properties, thus reducing microbial growth in cut flower solutions (12). (13) found that the use of nanofibers containing lavender oil slowed the release of the compounds and reduced the growth of *E. coli* and *Staphylococcus aureus* compared to other treatments, improving the quality of the flowers and extending their vase life. (14) indicated that the use of silver nitrate ($AgNO_3$) in preservation solutions effectively contributes to extending the vase life of rose flowers, as treatment with 50 ppm of $AgNO_3$ with the addition of sucrose showed a significant improvement in water absorption, reduced bacterial growth, and increased vase life compared to the control treatment. (15) investigated the effects of several preservation solutions on (*R. hybrida* L.) including silver nitrate (SN) and silver thiosulfate (STS). Their results showed that STS was the most effective, extending shelf life to 19.9 days compared to 11.8 days for the control, maintaining fresh weight, positive water balance, and

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chlorophyll and sucrose content, and inhibiting microbial growth. Silver nitrate (SN) also improved water absorption and inhibited microbial growth, highlighting the role of silver compounds as key agents in post-harvest flower preservation techniques. (16) demonstrated the effectiveness of silver nitrate nanoparticles (AgNPs) in extending the vase life of cut roses. The initial treatment (pulse treatment) with 50 mg $L^{-1}$of AgNPs significantly extended the vase life and improved the flower quality compared to the control treatment. The research aims to evaluate the effect of silver nitrate, nano-silver nitrate, citric acid, ethanol, and lavender oil on extending the vase life of cut rose flowers, to develop effective and sustainable preservation solutions that support sustainable development.

The research aims to develop effective and sustainable preservation solutions using silver nitrate, nano silver nitrate, citric acid, ethanol, and lavender oil to extend the vase life of cut roses and contribute to promoting sustainable development principles.

MATERIALS AND METHODS

The experiment was conducted using a completely randomized factorial design (CRD) with three replicates and five flowers per replicate. Data were analyzed using (17), and Duncan's multiple range test was used at a 5% significance level to compare means between treatments. Rose flowers were collected at the early bloom stage during the early morning hours, and healthy flowers were selected. The lower leaves were then removed, and the stems were placed directly in clean, sterile distilled water for several hours to condition the vascular tissues and maintain tissue viability before being treated with different preservation solutions. The flowers were then transferred to the laboratory, and the stems were trimmed at an oblique angle to facilitate the absorption of the solutions, and their length was standardized to 25 cm. Excess leaves below the water level were removed to prevent gas formation in the xylem tissues of the rose flowers (18).

The experiment involved combining two concentrations of sucrose (0 and 20 g/L) with nine types of preservation solutions Figure (2):

1. Distilled water: used as a control.
2. Silver nitrate ($AgNO_3$) at concentrations of 40 and 80 mg L^{-1}.
3. Nano-silver nitrate (nano $AgNO_3$) at concentrations of 5 and 10 mg L^{-1}.
4. Citric acid ($C_6 H_8 O_7$) at concentrations of 200 and 400 mg L^{-1}.

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5. Ethyl alcohol (C_2H_5OH) at a concentration of 10%.
6. Lavender oil at a concentration of 2%.

After treating the flowers with the preservation solutions for 24 hours, the treated flowers were transferred to 200 ml glass bottles containing only distilled water at room temperature (25 ± 1°C). The vase life was monitored and various quality indicators were measured until the end of the experiment (19).
The following experimental characteristics were recorded:
1. Flower vase life (days):
The number of days from the time the flowers were placed in the preservative solutions until 20% of the petals darkened was calculated.
2. Volume of water uptake (ml):
The volume of water absorbed by the flowers over the duration of their stay in the vase was calculated by calculating the volume of water absorbed every five days and calculating the difference at the start and end of the experiment.
3. Percentage of weight loss (%):
The percentage of weight loss was calculated using a sensitive balance according to the following relationship:

XPercentage weight loss (%)=	Wet weight at the beginning of the flower's lifespan - Wet weight at the end of the flower's lifespan	×100
	Wet weight at the beginning of the flower's lifespan	

4. Flower diameter %: The flower diameter was calculated at the beginning of the
beginning of the
experiment, after three, six, and nine days, and at the end of the vase life using a caliper, and the percentage was calculated using the following relationship (20):

Change in flower diameter (%) =	Diameter at the beginning of the vase life - Diameter at the end of the vase life	× 100
	Diameter at the beginning of the vase life	

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Figure (2): Commercial packaging for the compounds used in the study (A)Nanosilver, (B)Citric Acid, (C)Lavender Oil.

RESULTS AND DISCUSSION

Data from Table (1) indicate that the preservation solutions used in the study had a significant effect on the flowering lifespan of roses for most of the studied traits. It was noted that the use of 10 mg/L nano-silver, 10% ethyl alcohol, and 2% lavender oil recorded the highest significant values, reaching 16.33, 16.83, and 16.55 days, respectively. The lowest significant value, 11.17 days, was recorded for the control treatment. It was observed that the use of sucrose at a concentration of 20 g L^{-1} extended the flower arrangement lifespan to 16.83 days, compared to 13.82 days for the treatment without sucrose.

Data from the two-way interaction between the use of sucrose and the preservation solutions indicated that the addition of sucrose at a concentration of 20 g L^{-1} and the treatment with both nano-silver at concentrations of 5 and 10 mg L-1, ethyl alcohol at a concentration of 10%, and lavender oil at a concentration of 2% recorded the highest significant values, reaching 17.79, 17.56, 17.30, and 16.97 days, compared to the lowest significant value of 10.01 days for the control treatment.

Table (1) The effect of sucrose treatment, flower preservation solutions, and the interaction between them on the characteristic of flower coordination age (day).

Preservative Solutions	Distilled water	Silver nitrate 40 mg L^{-1}	Silver nitrate 80 mg L^{-1}	Nano silver 5 mg L^{-1}	Nano silver 10 mg L^{-1}	Citric acid 200 mg L^{-1}	Citric acid 400 mg L^{-1}	Ethyl alcohol 10%	Lavender oil 2%	Effect of sucrose
Sucrose-Free	10,01 d	12.02 dc	13.11 b-d	15.33 bc	15.10 bc	13.12 b-d	13.22 b-d	16.36 a	16.12 ab	13.82 b
Sucrose 20 g L^{-1}	12,32 cd	14.64 a-c	14.56 bc	17.79 a	17.56 a	15.21 a-c	16.11 ab	17.30 a	16.97 a	15.83 a
Effect of Preservation Solution Treatments	11,17 e	13.33 d	13.84 cd	16.56 a	16.33 a	14.17 bc	14.67 bc	16.83 a	16.55 a	

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Values with the same letters for each factor individually in the same column are not significantly different according to Duncan's multiple range test at the 0.05 probability level.

Table (2) shows that the highest significant value for the change in absorbed water volume (ml) was obtained when using both silver nitrate at a concentration of 80 mg L^{-1} and 40 mg L^{-1}, as well as when using ethyl alcohol at a concentration of 10%, reaching (30.15, 29.36, and 29.20) ml, respectively, compared to the lowest value for the control treatment, which reached 24.71 ml. It was noted that the use of sucrose at a concentration of 20% recorded the best significant value, 28.47 ml, compared to 27.27 ml when sucrose was not used. The data for the two-way interaction between the studied treatments in Table (2) also indicate that the treatment with a 20% sucrose solution interacted with both the use of silver nitrate at a concentration of 80 mg $L^{-1}$and the use of nanosilver solutions at concentrations of 5 and 10 mg. L^{-1} recorded the best significant values of 31.45, 30.44 and 30.05 ml, respectively, compared to the lowest significant value of 24.83 ml for the control treatment.

The results obtained from Table (3) show that the use of preservation solutions had a significant effect on the change in flower fresh weight (%). The best significant value was achieved when using both nanosilver at a concentration of 5 mg L^{-1} and citric acid at a concentration of 400 mg L^{-1}, reaching (28.22 and 27.77)%, respectively, compared to the lowest significant value when treated with silver nitrate at a concentration of 40 mg L^{-1}, reaching 23.27%. It was noted that not adding the sucrose solution recorded a significantly better value than adding sucrose for the change in flower fresh weight.

Data from the two-way interaction between the studied treatments indicate that the best significant value was achieved when not using sucrose, combined with the use of nanosilver at a concentration of 5 mg L-1, reaching 31.77%, compared to the lowest significant value for the control treatment, reaching 22.27%.

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Table (2) Effect of sucrose treatment, flower preservation solutions, and the interaction between them on the volume of absorbed water (ml).

Preservative Solutions	Distilled water	Silver nitrate 40 mg L^{-1}	Silver nitrate 80 mg L^{-1}	Nano silver 5 mg L^{-1}	Nano silver 10 mg L^{-1}	Citric acid 200 mg L^{-1}	Citric acid 400 mg L^{-1}	Ethyl alcohol 10%	Lavender oil 2%	Effect of sucrose
Sucrose-Free	24.83 b	24.5 b	29.85 ab	28.66 ab	26.27 ab	30.49 ab	26.52 ab	29.55 ab	24.72 ab	27.27 b
Sucrose 20 g L	24.59 b	31.45 a	30.44 a	30.05 a	28.68 ab	26.67 ab	25.91 ab	28.88 ab	29.59 ab	28.47 a
Effect of Preservation Solution Treatments	24.71 b	27.98 ab	30.15 a	29.36 a	27.45 ab	28.58 ab	26.22 ab	29.20 a	27.16 ab	

Values with the same letters for each factor individually in the same column are not significantly different according to Duncan's multiple range test at the 0.05 probability level.

Table (3) The effect of sucrose treatment, flower preservation solutions, and the interaction between them on the characteristic of change in the fresh weight of flowers (%)

Preservative Solutions	Distilled water	Silver nitrate 40 mg L^{-1}	Silver nitrate 80 mg L^{-1}	Nano silver 5 mg L^{-1}	Nano silver 10 mg L^{-1}	Citric acid 200 mg L^{-1}	Citric acid 400 mg L^{-1}	Ethyl alcohol 10%	Lavender oil 2%	Effect of sucrose
Sucrose-Free	22.27 d	2376 cd	23.93 cd	31.77 a	26.27 bc	27.36 bc	30.17 ab	25.37 cd	26.97 bc	26.43 a
Sucrose 20 g L	23.83 cd	22.77 cd	22.97 cd	24.66 cd	25.66 cd	24.80 cd	25.36 cd	23.76 cd	26.10 bc	24.06 b

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Effect of Preservation Solution Treatments	24.75 bc	23.27 c	23.45 bc	28.22 a	24.27 bc	26.05 a-c	27.77 a	24.57 bc	26.53 ab	

Values with the same letters for each factor individually in the same column are not significantly different according to Duncan's multiple range test at the 0.05 probability level.

It is noted from the data in Table (4) that the highest significant percentage change in flower diameter was achieved when using both nano silver at a concentration of 10 mg L-1 and lavender oil at a concentration of 2%, reaching (46.73 and 45.05) %, compared to the lowest significant values when treated with both the control treatment and when using silver nitrate at a concentration of 40 mg L-1, reaching (36.50 and 36.83)%.

Table (4) The effect of sucrose treatment, flower preservation solutions, and the interaction between them on the characteristic of change in flower diameter (%).

Preservative Solutions	Distilled water	Silver nitrate 40 mg L^{-1}	Silver nitrate 80 mg L^{-1}	Nano silver 5 mg L^{-1}	Nano silver 10 mg L^{-1}	Citric acid 200 mg L^{-1}	Citric acid 400 mg L^{-1}	Ethyl alcohol 10%	Lavender oil 2%	Effect of sucrose
Sucrose-Free	33.60 g	34.46 fg	37.93 fg	43.23 a-e	45.7 ab	43.7 a-e	43.1 a-e	40.26 c-f	45.3 a-d	40.81 b
Sucrose 20 g L	39.40 c-f	39.20 c-f	45.97 a-d	42.23 a-e	47.76 a	43.87 a-e	45.46 a-c	46.65 a	44;8 a-d	43.92 a
Effect of Preservation Solution Treatments	36.50 c	36.83 c	41.95 b	42.73 b	46.73 a	43.78 ab	44.28 ab	43.41 ab	45.05 a	

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Values with the same letters for each factor individually in the same column are not significantly different according to Duncan's multiple range test at the 0.05 probability level.

It was noted that the treatment with sucrose at a concentration of 20 g L-1 recorded the highest significant value for change in flower diameter, reaching 43.92%, compared to 40.81% for the control treatment. The data of the two-way interaction indicate that the treatment with sucrose at a concentration of 20 g L-1 interacted with both the treatment with nano-silver at a concentration of 10 mg L-1, as well as the interaction of sucrose and the treatment with ethyl alcohol at a concentration of 10%, as it recorded the best significant values, reaching (47.67 and 46.65)%, respectively, compared to the lowest significant value for the control treatment, which reached 33.60%.

Discussion

The quality of cut flowers after harvest depends largely on the conditions preceding the cutting and the subsequent processing methods. Inappropriate postharvest processing disrupts the water balance and alters metabolic processes, accelerating the closure of water vessels and reducing the flower's vase life (21). A study by (22) indicates that the quality of cut flowers is significantly affected by pre-harvest cultivation conditions, such as nutrition, irrigation, and light, which are reflected in their vase life after cutting. This explains the different responses of flowers to different preservation solutions, as flowers from plants grown under ideal conditions were better able to absorb water and resist aging (23).

The research results show that the sucrose solution had a significant effect on most of the obtained values. Adding sucrose to preservation solutions significantly improves the vase life of cut flowers. It is a primary source of energy, contributing to improved intracellular water balance, leading to cell expansion and petal opening. Moreover, sucrose enhances water absorption, and the role of sugars in prolonging vase life by improving water balance, as well as its role in expanding petals and opening flowers due to the expansion of cells that require water flow into the cell due to the high sugar concentration. The use of sucrose causes an increase in nutrients in the mesophyll layer and leads to the inhibition of ethylene production, as flowers treated with sucrose have an increased respiration rate, which leads to the accumulation of CO2 in their tissues, which acts as an antagonist to the action of ethylene. Sucrose improves flower color by stimulating the gene responsible for anthocyanin synthesis, which improves the fresh weight of flowers and delays the signs of aging (24). This is consistent with what was shown by (25). It was also observed that the use of sucrose with acidic solution extended the vase life and other studied characteristics. This may be due to the fact that the acidity level affects the breakdown of pectins and other cell components, thus reducing stem blockage due to the breakdown products of pectin, carbohydrates and proteins. Therefore, lowering the acidity level of the water or preservative solution reduces physiological stem blockage (26).

The results indicate that silver nitrate, nanosilver nitrate, and lavender oil are effective in extending the vase life of cut roses, although their mechanisms of action differ(27). Silver nitrate ($AgNO_3$) inhibits microbial activity in the preservation solution, preventing the blockage of water-carrying vessels in the stems and maintaining water balance within the tissues. It also inhibits ethylene production. Silver nitrate ions and nanosilver nitrate are characterized by their rapid penetration into ethylene sites, inhibiting its production. Furthermore, this ion moves slowly in the stems of cut flowers, thus delaying flower aging and damage. Studies have shown that nanosilver acts as an antibacterial. These substances increase the permeability of nutrients, especially sucrose, as well as water permeability, and preserve chlorophyll and prevent its breakdown (28). Ethanol at moderate concentrations contributes to extending the vase life of roses by reducing microbial growth, inhibiting the effect of ethylene, and slowing the senescence process in the petals. This is consistent with (29), who indicated that combining 4% ethanol with 150 mg/L sodium benzoate enhanced water absorption and increased the lifespan of Avalanche roses to approximately 13 days, highlighting the effectiveness of this treatment and the importance of its use. Appropriate concentrations to avoid cytotoxicity. The research results also showed that lavender oil extended the vase life of roses due to its antibacterial and antioxidant properties. It reduces microbial growth in the solution and maintains vessel cleanliness. It also inhibits some enzymes that lead to premature aging. This improves water absorption, prolongs flower life, and preserves color quality and petal elasticity (30). This is consistent with what (31) demonstrated, stating that adding the oil at a concentration of 100–150 mg/L to preservation solutions reduces bacterial growth and prevents clogging of xylem vessels, thus maintaining water absorption and improving flower quality after harvest(32).

CONCLUSIONS

The results showed that the addition of sucrose, nanosilver nitrate, ethyl alcohol, and lavender oil improved the vase life of rose flowers by enhancing water uptake and reducing microbial activity. Citric acid also improved water flow by lowering the solution pH. The combination of sucrose and either nanosilver, ethyl alcohol, or lavender oil achieved the best results for most of the studied traits.

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CONFLICT OF INTEREST

All ethical guidelines regarding nanofertilizer preparation and treatment of ***Rosa* × *Hybrida* L.** Plants have been implemented within the limits of health safety and care issued by national and international organizations in this report.

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