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ENHANCEMENT OF POSTHARVEST QUALITY AND VASE LIFE OF CUT GERBERA (*GERBERA JAMESONII*) FLOWERS USING SUCROSE AND SILVER NITRATE PRESERVATIVE SOLUTIONS

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ABSTRACT
The postharvest longevity of cut gerbera (*Gerbera jamesonii* Bolus ex Hooker F.) flowers is limited by rapid physiological deterioration, microbial contamination, and water stress. This study evaluated the efficacy of sucrose and silver nitrate ($AgNO_3$) preservative solutions, individually and in combination, on the postharvest quality parameters of cut gerbera flowers. Three sequential experiments were conducted: Experiment I standardized sucrose concentrations (2%, 3%, 4%, 5%, and 6%); Experiment II standardized $AgNO_3$ concentrations (20, 30, and 50 ppm); and Experiment III evaluated the combined effect of optimal concentrations (4% sucrose + 30 ppm $AgNO_3$). Parameters assessed included fresh weight retention, flower diameter, visual quality score, wilting percentage, water uptake, and vase life. Results demonstrated that 4% sucrose significantly improved visual quality score (4.33) and reduced wilting (56.66%) compared to the control. Among $AgNO_3$ treatments, 30 ppm exhibited superior performance with the highest visual score (6.67) and lowest wilting percentage (33.33%). The combined treatment of 4% sucrose + 30 ppm $AgNO_3$ yielded the most favorable outcomes, achieving a visual quality score of 5.0, wilting percentage of 50%, water uptake of 35.33 mL, and vase life exceeding 11 days. All treatment effects were statistically significant (ANOVA, $p < 0.05$). These findings indicate that the synergistic application of 4% sucrose and 30 ppm $AgNO_3$ effectively extends the postharvest life and maintains the ornamental quality of cut gerbera flowers, offering practical implications for commercial floriculture operations.

Keywords: *Cut flowers; Floral preservatives; Postharvest physiology; Senescence; Vase Life Extension; Silver Nitrate; Sucrose*

INTRODUCTION
Floriculture represents one of the most rapidly expanding sectors within horticulture, driven by escalating demand for ornamental plants and cut flowers in both domestic and international markets. Cut flowers are extensively utilized for bouquets, floral arrangements, interior decoration, and ceremonial purposes, owing to their aesthetic appeal and commercial value. The quality and marketability of cut flowers are primarily determined by their freshness, visual appearance, and postharvest longevity following harvest (Vehniwal & Abbey, 2019).

Gerbera (*Gerbera jamesonii* Bolus ex Hooker F.), a member of the family Asteraceae, ranks among the most commercially significant ornamental cut flowers cultivated worldwide. Its popularity stems from its attractive flower morphology, extensive color palette, and long flower stalks that render it particularly suitable for floral decorations (Banaee *et al.,* 2013). The species occupies a prominent position in the global floriculture industry due to high consumer preference and export value (Vehniwal & Abbey, 2019). Despite its commercial importance, gerbera flowers are highly perishable following harvest and exhibit a characteristically short postharvest life under ambient environmental conditions.

Following detachment from the mother plant, cut flowers continue to undergo physiological and biochemical activities that result in gradual quality deterioration during storage and display. Processes including respiration, transpiration, and senescence progressively reduce freshness and ornamental value

(Vehniwal & Abbey, 2019). Common postharvest problems in gerbera include stem bending, wilting, loss of turgidity, and reduction in flower diameter, all of which adversely affect marketability and consumer acceptance (Banaee et al., 2013). Water imbalance and microbial contamination are considered primary causes of early deterioration, as microorganisms colonizing vase solutions may occlude xylem vessels and impede normal water uptake through the stem (Doorn & Stead, 1997). Reduced hydraulic conductivity resulting from vascular blockage ultimately leads to wilting and compromised flower quality (Hardenburg *et al.,* 1986).

Several preservative solutions have been developed to improve flower longevity and maintain freshness during transportation and storage. Floral preservatives generally incorporate sugars, antimicrobial compounds, and growth-regulating substances that collectively improve water uptake and delay senescence (Vehniwal & Abbey, 2019). The effectiveness of these solutions depends largely on their capacity to minimize microbial proliferation and maintain hydraulic conductivity in flower stems (Elgimabi, 2011). Appropriate preservative treatments have been shown to reduce vascular occlusion and improve water balance in cut flowers, thereby extending keeping quality after harvest (Hardenburg *et al.,* 1986).

Sucrose is among the most widely used carbohydrate sources in floral preservative solutions. Since detached flowers lose their continuous carbohydrate supply from photosynthesis, exogenous sugar supplementation becomes necessary to sustain metabolic activities and flower opening. Sucrose functions as a respiratory substrate, providing energy required for maintenance of cellular turgidity and delayed senescence (Butt, 2005). It also maintains osmotic balance and improves water uptake in flower tissues, thereby enhancing postharvest quality (Pun *et al.,* 2005). Numerous studies have reported beneficial effects of sucrose treatments on flower longevity; however, the optimal concentration varies among species and cultivars, and excessive concentrations may promote microbial growth and impair water uptake (Han, 1992; Locke, 2010)

Silver nitrate ($AgNO_3$) is among the most extensively studied chemical preservatives for cut flowers. Silver ions exert potent antimicrobial activity against bacteria and fungi present in vase solutions, thereby reducing stem-end blockage and maintaining vascular conductivity (Elgimabi, 2011). Additionally, silver ions inhibit ethylene action by competing with ethylene receptors, thereby delaying senescence and extending vase life (Yang & Hoffman, 1984). The effectiveness of silver nitrate has been demonstrated in several cut flower species; however, the optimal concentration for gerbera requires systematic evaluation, as insufficient concentrations may not provide adequate antimicrobial control, while excessive concentrations may exert phytotoxic effects (Ohkawa *et al.,* 1999).

The combination of sucrose and antimicrobial compounds in preservative solutions has been reported to produce synergistic effects superior to those obtained with individual components (Cho & Lee, 1980). Sucrose provides the energy substrate required for physiological maintenance, while antimicrobial agents preserve xylem functionality by limiting microbial colonization. Despite the demonstrated efficacy of combined treatments in other ornamental species, comparable information for gerbera remains limited, and the interaction between optimized concentrations of sucrose and silver nitrate has not been extensively evaluated under diverse environmental and handling conditions (Damunupola & Joyce, 2008).

In view of these limitations, the present investigation was undertaken to systematically evaluate the postharvest efficacy of sucrose and silver nitrate, individually and in combination, on the vase life and quality parameters of cut gerbera flowers. The study was designed in three sequential stages: standardization of sucrose concentration, standardization of silver nitrate concentration, and evaluation of the combined preservative effect. The findings are expected to contribute to the development of an effective and economically feasible preservative solution for improving the postharvest quality and longevity of cut gerbera flowers under local commercial conditions.

MATERIALS AND METHODS

2.1 Plant Material and Experimental Location

Freshly harvested gerbera flowers (*Gerbera jamesonii L.*) of uniform size, colour, and developmental maturity were used as the experimental material. Flowers were obtained from a commercial flower supplier who procured freshly harvested blooms directly from certified flower growers. Only healthy flowers free from mechanical injury, pest infestation, disease symptoms, petal damage, stem defects, or physiological disorders were selected for the study. Immediately following procurement, flowers were transported carefully to minimize physical damage. Stems were recut using a clean, sharp blade and standardized to a uniform length of 20 cm. Flowers were selected to ensure uniformity in flower diameter, stem thickness, and developmental stage. Following 24 hours of initial observation, stem ends were recut and maintained at a uniform length of 17 cm throughout the remaining experimental period, ensuring consistency in water uptake measurements and minimizing variation arising from differences in stem length.

2.2 Preparation of Preservative Solutions

All glassware and apparatus were thoroughly cleaned prior to use to prevent contamination of treatment solutions. Distilled water was used throughout the investigation for preparation of all treatment solutions and served as the control treatment.

2.2.1 Sucrose Solutions

Sucrose solutions of different concentrations (2%, 3%, 4%, 5%, and 6% w/v) were prepared by dissolving accurately weighed quantities of analytical-grade sucrose in distilled water. The required mass of sucrose was determined using an electronic balance and dissolved completely with continuous stirring. Solutions were prepared freshly before initiation of the experiment to ensure uniformity and accuracy.

2.2.2 Silver Nitrate Solutions

Silver nitrate solutions were prepared from a previously prepared stock solution. Appropriate volumes of the stock solution were diluted with distilled water to obtain the required concentrations of 20, 30, and 50 ppm $AgNO_3$. All solutions were prepared using calibrated volumetric glassware. Silver nitrate solutions were protected from unnecessary light exposure during preparation and handling to prevent photoreduction.

2.2.3 Combined Preservative Solution

Based on the results of the standardization experiments, the most effective concentrations of sucrose and silver nitrate were selected and combined to prepare a preservative solution containing 4% sucrose + 30 ppm $AgNO_3$. This combined solution was used in Experiment III to evaluate the synergistic effect of carbohydrate supplementation and antimicrobial treatment on the vase life of cut gerbera flowers.

2.3 Experimental Design and Treatments

The investigation comprised three independent, sequential experiments. Each experiment incorporated different treatments with three replications per treatment. Individual flowers served as experimental units and were maintained separately in boiling tubes containing the designated treatment solution. Initially, 30 mL of treatment solution was provided to each flower in all experiments. Flowers were maintained under identical environmental conditions throughout the study period. Observations were recorded daily between 07:00 and 08:00 h until flowers lost their ornamental acceptability.

Table 1. Treatments for Experiment I: Standardization of sucrose concentration

Treatment	Composition
T_0	Distilled water (Control)
T_1	2% sucrose
T_2	3% sucrose
T_3	4% sucrose
T_4	5% sucrose
T_5	6% sucrose

Table 2. Treatments for Experiment II: Standardization of silver nitrate concentration

Treatment	Composition
T_0	Distilled water (Control)
T_1	4% sucrose (best from Experiment I)
T_2	20 ppm $AgNO_3$
T_3	30 ppm $AgNO_3$
T_4	50 ppm $AgNO_3$

Table 3. Treatments for Experiment III: Combined preservative evaluation

Treatment	Composition
T_0	Distilled water (Control)
T_1	4% sucrose (from Experiment I)
T_2	30 ppm $AgNO_3$ (from Experiment II)
T_3	4% sucrose + 30 ppm $AgNO_3$ (Combined)

2.4 Data Collection and Measurements

The following parameters were recorded daily from Day 0 until vase life termination:

- **Initial Fresh Weight (g):** The initial fresh weight of each flower was recorded immediately before placement in the treatment solution.
- **Fresh Weight (g):** Fresh weight was measured daily using a calibrated electronic weighing balance.
- **Change in Fresh Weight (g):** Daily variation in fresh weight was calculated relative to the initial fresh weight.
- **Remaining Solution Volume (mL):** The volume of solution remaining in each boiling tube was measured daily.
- **Water Uptake (mL):** Water uptake was determined as the difference between the initial solution volume and the remaining solution volume: Water Uptake (mL) = Initial Solution Volume − Remaining Solution Volume.
- **Flower Diameter (cm):** Flower diameter was measured periodically using a ruler and expressed in centimetres.
- **Visual Quality Score (0–10):** Visual quality was assessed based on freshness, colour retention, petal appearance, stem rigidity, and overall ornamental value, using a standardized 0–10 scale.
- **Percentage Wilting (%):** The extent of wilting was estimated by observing petal drooping, discolouration, loss of turgidity, and deterioration of floral appearance.
- **Vase Life (days):** Vase life was recorded as the number of days from treatment initiation until the flower lost its decorative value and became unsuitable for display.

2.5 Statistical Analysis

Data from three replications per treatment were averaged for each parameter. One-way Analysis of Variance (ANOVA) was performed on final-day parameter values for each experiment. F-statistics and corresponding p-values are reported; treatment effects significant at $p < 0.05$ are denoted with an asterisk (*). Non-significant results are denoted NS. Mean values were tabulated and graphically represented to facilitate comparative evaluation of treatments.

RESULTS

The investigation employed a three-stage experimental approach to identify an effective postharvest preservative solution for cut gerbera flowers. Experiment I standardized the optimum sucrose concentration; Experiment II standardized the optimum silver nitrate concentration using the best-performing sucrose treatment as a reference; and Experiment III evaluated the combined effect of the optimal concentrations identified from the preceding experiments. Parameters assessed included fresh weight, flower diameter, visual quality score, wilting percentage, water uptake, and vase life. Statistical significance was determined by one-way ANOVA on final-day values ($n = 3$ per treatment).

3.1 Experiment I: Effect of Sucrose Concentrations on Postharvest Quality

Experiment I evaluated six treatments — distilled water control (T_0), 2% sucrose (T_1), 3% sucrose (T_2), 4% sucrose (T_3), 5% sucrose (T_4), and 6% sucrose (T_5) — on the postharvest quality of cut gerbera flowers over eight days. Mean values for initial and final-day parameters, cumulative water uptake, and ANOVA results are presented in Table 4.

Table 4. Effect of different sucrose concentrations on postharvest quality parameters of cut gerbera (Experiment I). Values are means of three replications.

Treatment	Description	Initial Fresh Wt. (g)	Final Fresh Wt. (g)	Initial Flower Ø (cm)	Final Flower Ø (cm)	Final Visual Score (0–10)	Final Wilting (%)	Total Water Uptake (mL)	Vase Life (Days)
T_0	Distilled water (Control)	16.00	3.66	9.50	3.93	1.00	90.00	13.67	8
T_1	2% Sucrose	20.66	5.66	9.90	5.53	1.00	90.00	16.34	8
T_2	3% Sucrose	16.33	3.00	9.43	4.86	1.33	86.66	13.34	8
T_3	4% Sucrose	17.77	5.33	10.26	4.23	4.33	56.66	19.67	8
T_4	5% Sucrose	20.33	7.66	10.27	5.40	3.33	66.66	20.67	8
T_5	6% Sucrose	19.00	7.66	10.23	6.30	2.33	76.66	27.68	8
F value	—	—	136.821	—	35.707	349.166	36.675	94.353	—
p value	—	—	< 0.0001	—	< 0.0001	< 0.0001	< 0.0001	< 0.0001	—

Significant at $p < 0.05$ (ANOVA on final-day values, $n = 3$ per treatment); NS – Not Significant

3.1.1 Fresh Weight

Final fresh weight on Day 8 showed highly significant differences among treatments ($F = 136.821$, $p < 0.0001$). T_4 (5% sucrose) and T_5 (6% sucrose) recorded the highest final fresh weights (7.66 g each), followed by T_1 (2% sucrose, 5.66 g), T_3 (4% sucrose, 5.33 g), T_0 (control, 3.66 g), and T_2 (3% sucrose, 3.00 g). A progressive decline in fresh weight was observed from Day 0 onwards, reflecting the inevitable transpirational water loss following detachment from the mother plant. The relatively higher fresh weight retention in T_4 and T_5 suggests that elevated sucrose concentrations contributed to improved osmotic water absorption. However, fresh weight alone does not reflect ornamental acceptability; visual quality and wilting data revealed that T_3 (4% sucrose), despite a slightly lower final fresh weight than T_4 and T_5, maintained markedly superior flower quality throughout the experiment. This dissociation between fresh weight retention and visual quality indicates that higher sucrose concentrations may accelerate osmotic uptake without sustaining cellular integrity or delaying senescence.

3.1.2 Flower Diameter

Final flower diameter on Day 8 showed highly significant differences among treatments ($F = 35.707$, $p < 0.0001$). T_5 (6% sucrose) recorded the largest final diameter (6.30 cm), followed by T_4 (5% sucrose, 5.40 cm), T_1 (2% sucrose, 5.53 cm), T_2 (3% sucrose, 4.86 cm), T_3 (4% sucrose, 4.23 cm), and T_0 (control, 3.93 cm). The larger final diameters observed in T_4 and T_5 are attributable to continued flower opening facilitated by higher sucrose availability. However, the enlarged diameter in these treatments was accompanied by advanced senescence and loss of petal firmness, suggesting that high sucrose concentrations may accelerate flower opening without prolonging ornamental quality. T_3 maintained a balanced progression of flower development with better retention of petal integrity.

3.1.3 Visual Quality Score

Visual quality score on Day 8 showed highly significant differences among treatments ($F = 349.166$, $p < 0.0001$). T_3 (4% sucrose) recorded the highest visual quality score (4.33), followed by T_4 (5% sucrose, 3.33), T_5 (6% sucrose, 2.33), T_2 (3% sucrose, 1.33), and T_0 and T_1 (both 1.00). The superior visual quality of T_3 indicates that 4% sucrose provided an optimal balance between carbohydrate supplementation and maintenance of normal physiological processes. Higher concentrations (T_4 and T_5) resulted in lower visual quality scores, suggesting that excessive sucrose may impair cellular integrity through osmotic stress or by promoting microbial proliferation in the vase solution.

3.1.4 Wilting Percentage

Wilting percentage on Day 8 showed highly significant differences among treatments ($F = 36.675$, $p < 0.0001$). T_3 (4% sucrose) recorded the lowest wilting percentage (56.66%), followed by T_4 (66.66%), T_5 (76.66%), T_2 (86.66%), and T_0 and T_1 (both 90.00%). The substantially lower wilting percentage in T_3 corroborates the visual quality data and confirms that 4% sucrose was the most effective concentration for maintaining flower turgidity and delaying senescence.

3.1.5 Water Uptake and Vase Life

Total cumulative water uptake showed highly significant treatment differences ($F = 94.353$, $p < 0.0001$). T_5 (6% sucrose) recorded the highest water uptake (27.68 mL), followed by T_3 (19.67 mL), T_4 (20.67 mL), T_1 (16.34 mL), T_0 (13.67 mL), and T_2 (13.34 mL). The elevated water uptake in T_5 reflects increased osmotic activity driven by high sucrose concentration, rather than improved physiological maintenance. Vase life was uniform at 8 days across all treatments, indicating that sucrose concentration, within the range tested, did not extend vase life duration in this experiment. Based on the overall evaluation of visual quality, wilting percentage, and water uptake, T_3 (4% sucrose) was selected as the optimal sucrose concentration for subsequent experiments.

3.2 Experiment II: Effect of Silver Nitrate Concentrations on Postharvest Quality

Experiment II evaluated five treatments — distilled water control (T_0), 4% sucrose (T_1, best treatment from Experiment I), 20 ppm $AgNO_3$ (T_2), 30 ppm $AgNO_3$ (T_3), and 50 ppm $AgNO_3$ (T_4) — on postharvest quality of cut gerbera flowers over seven days. Results are presented in Table 5.

Table 5. Effect of different silver nitrate concentrations on postharvest quality parameters of cut gerbera (Experiment II). Values are means of three replications.

Treatment	Description	Initial Fresh Wt. (g)	Final Fresh Wt. (g)	Initial Flower Ø (cm)	Final Flower Ø (cm)	Final Visual Score (0–10)	Final Wilting (%)	Total Water Uptake (mL)	Vase Life (Days)
T_0	Distilled water (Control)	19.00	5.33	10.57	5.47	1.33	86.67	20.12	7
T_1	4% Sucrose (Expt. I best)	21.33	6.00	10.47	5.20	4.67	53.33	22.87	7
T_2	20 ppm $AgNO_3$	19.00	5.00	10.63	5.63	2.33	76.67	21.40	7
T_3	30 ppm $AgNO_3$	17.33	8.33	9.47	6.30	6.67	33.33	21.20	7
T_4	50 ppm $AgNO_3$	24.67	6.67	10.70	5.73	2.67	73.33	21.97	7
F value	—	—	51.451	—	6.169	338.211	119.736	2.654 (NS)	—
p value	—	—	< 0.0001	—	0.0091	< 0.0001	< 0.0001	0.0960 (NS)	—

Significant at $p < 0.05$; NS – Not Significant

3.2.1 Fresh Weight and Flower Diameter

Final fresh weight on Day 7 showed highly significant differences among treatments ($F = 51.451$, $p < 0.0001$). T_3 (30 ppm $AgNO_3$) recorded the highest final fresh weight (8.33 g), followed by T_4 (50 ppm, 6.67 g), T_1 (4% sucrose, 6.00 g), T_0 (control, 5.33 g), and T_2 (20 ppm, 5.00 g). Flower diameter on Day 7 also showed significant treatment differences ($F = 6.169$, $p = 0.0091$). T_3 (30 ppm $AgNO_3$) recorded the largest final diameter (6.30 cm), comparable to T_4 (5.73 cm), T_2 (5.63 cm), T_1 (5.20 cm), and T_0 (5.47 cm). The superior fresh weight and flower diameter retention in T_3 indicate that 30 ppm $AgNO_3$ effectively maintained tissue hydration and delayed senescence.

3.2.2 Visual Quality Score and Wilting Percentage

Visual quality score on Day 7 showed highly significant differences ($F = 338.211$, $p < 0.0001$). T_3 (30 ppm $AgNO_3$) recorded the highest visual score (6.67), substantially higher than T_1 (4% sucrose, 4.67), T_4 (50 ppm, 2.67), T_2 (20 ppm, 2.33), and T_0 (control, 1.33). Wilting percentage on Day 7 showed highly significant differences ($F = 119.736$, $p < 0.0001$). T_3 recorded the lowest wilting percentage (33.33%), followed by T_1 (53.33%), T_4 (73.33%), T_2 (76.67%), and T_0 (86.67%). The markedly superior visual quality and reduced wilting in T_3 demonstrate that 30 ppm $AgNO_3$ was the most effective concentration for maintaining ornamental quality. The lower performance of 50 ppm $AgNO_3$ suggests that excessive silver ion concentrations may exert phytotoxic effects on flower tissues.

3.2.3 Water Uptake and Vase Life

Total water uptake did not differ significantly among treatments ($F = 2.654$, $p = 0.0960$, NS), indicating that silver nitrate concentration did not substantially alter the total volume of solution absorbed over the experimental period. Vase life was uniform at 7 days across all treatments. Based on the overall evaluation of visual quality, wilting percentage, and fresh weight retention, T_3 (30 ppm $AgNO_3$) was selected as the optimal silver nitrate concentration for the combined treatment experiment.

3.3 Experiment III: Combined Effect of Sucrose and Silver Nitrate on Postharvest Quality

Experiment III evaluated four treatments — distilled water control (T_0), 4% sucrose (T_1), 30 ppm $AgNO_3$ (T_2), and the combined solution of 4% sucrose + 30 ppm $AgNO_3$ (T_3) — over eleven days. During the experiment, T_3 exhibited significantly higher solution uptake compared with other treatments;

Table 6. Effect of combined sucrose and silver nitrate treatment on postharvest quality parameters of cut gerbera (Experiment III). Values are means of three replications.

Treatment	Description	Initial Fresh Wt. (g)	Final Fresh Wt. (g)	Initial Flower Ø (cm)	Final Flower Ø (cm)	Final Visual Score (0–10)	Final Wilting (%)	Total Water Uptake (mL)	Vase Life (Days)
T_0	Distilled water (Control)	15.33	5.33	9.10	4.57	0.00	100.00	25.67	10
T_1	4% Sucrose (from Expt. I)	15.33	5.67	8.53	6.17	0.00	100.00	32.00	11
T_2	30 ppm $AgNO_3$ (from Expt. II)	16.33	6.33	8.90	5.07	1.33	86.67	30.00	11
T_3	4% Sucrose + 30 ppm $AgNO_3$	15.67	8.67	8.97	6.63	5.00	50.00	35.33†	11+
F value	—	—	61.850	—	33.927	695.321	139.530	20.425	—
p value	—	—	< 0.0001	—	< 0.0001	< 0.0001	< 0.0001	0.0004	—

Significant at $p < 0.05$; † Total volume supplied to T_3 was 40 mL (additional 5 mL on Day 6 and Day 7); all other treatments received 30 mL throughout.

consequently, an additional 5 mL of fresh treatment solution was supplied on Day 6 and another 5 mL on Day 7, bringing the total volume supplied to T_3 to 40 mL, compared with 30 mL for all other treatments. Results are presented in Table 6.

3.3.1 Fresh Weight and Flower Diameter

Final fresh weight on Day 11 showed highly significant treatment differences ($F = 61.850$, $p < 0.0001$). T_3 (combined treatment) recorded the highest final fresh weight (8.67 g), followed by T_2 (30 ppm $AgNO_3$, 6.33 g), T_1 (4% sucrose, 5.67 g), and T_0 (control, 5.33 g). Flower diameter on Day 11 also showed highly significant differences ($F = 33.927$, $p < 0.0001$). T_3 recorded the largest final diameter (6.63 cm), followed by T_1 (6.17 cm), T_2 (5.07 cm), and T_0 (4.57 cm). The superior fresh weight and flower diameter of T_3 indicate that the combined treatment effectively maintained tissue hydration and supported continued flower development over the extended experimental period.

3.3.2 Visual Quality Score and Wilting Percentage

Visual quality score on Day 11 showed highly significant treatment differences ($F = 695.321$, $p < 0.0001$). T_3 (combined treatment) recorded the highest visual score (5.00), compared with T_2 (1.33), while T_0 and T_1 both recorded scores of 0.00 on the final day, indicating complete loss of ornamental acceptability. Wilting percentage on Day 11 showed highly significant differences ($F = 139.530$, $p < 0.0001$). T_3 recorded the lowest wilting percentage (50.00%), compared with T_2 (86.67%), T_1 (100.00%), and T_0 (100.00%). The markedly superior visual quality and reduced wilting in T_3 confirm that the combined treatment was substantially more effective than either preservative applied individually in maintaining ornamental quality over the extended vase period.

3.3.3 Water Uptake and Vase Life

Total water uptake showed significant treatment differences ($F = 20.425$, $p = 0.0004$). T_3 (combined treatment) recorded the highest water uptake (35.33 mL), followed by T_1 (32.00 mL), T_2 (30.00 mL), and T_0 (25.67 mL). The highest water uptake in T_3 reflects sustained physiological activity and improved hydration of the cut flowers, consistent with the superior visual quality and reduced wilting observed in this treatment. Vase life was extended to 11+ days in T_3, T_1, and T_2, compared with 10 days in T_0 (control), demonstrating that both individual and combined treatments contributed to vase life extension relative to the control.

DISCUSSION

4.1 Effect of Sucrose Concentrations

The results of Experiment I demonstrated that sucrose supplementation significantly influenced the postharvest quality of cut gerbera flowers, with 4% sucrose emerging as the optimal concentration. This finding is consistent with earlier reports demonstrating beneficial effects of sucrose on flower longevity in various ornamental species (., 2003; Butt, 2005; Pun et al., 2005)Sucrose functions primarily as a respiratory substrate, providing the energy required for maintenance of cellular turgidity, continued flower opening, and delayed senescence (Butt, 2005). The superior performance of 4% sucrose in terms of visual quality score and wilting percentage, compared with both lower and higher concentrations, indicates that an optimal carbohydrate level is critical for maximizing postharvest benefits.

The relatively lower visual quality scores and higher wilting percentages observed at 5% and 6% sucrose, despite higher fresh weight retention and water uptake, suggest that excessive sucrose concentrations may promote osmotic imbalance or stimulate microbial proliferation in the vase solution, ultimately compromising flower quality (Han, 1992; Locke, 2010) Similar observations of concentration-dependent sucrose effects have been reported in rose, carnation, and chrysanthemum (Meman & Dabhi, 2006; Reid & Jiang, 2012) The uniform vase life of 8 days across all sucrose treatments indicates that sucrose alone, within the tested range, was insufficient to extend vase duration, suggesting the need for complementary antimicrobial treatment to address vascular blockage (Doorn & Stead, 1997; Elgimabi, 2011).

4.2 Effect of Silver Nitrate Concentrations

Experiment II demonstrated that 30 ppm $AgNO_3$ was the most effective silver nitrate concentration for improving postharvest quality of cut gerbera flowers. Silver ions exert their beneficial effects primarily through two mechanisms: antimicrobial activity against bacteria and fungi colonizing vase solutions, and inhibition of ethylene action through competitive binding to ethylene receptors (Ohkawa et al., 1999; Yang & Hoffman, 1984) By reducing microbial colonization at stem ends, silver nitrate maintains xylem conductivity and facilitates continuous water movement through the stem, thereby delaying wilting and maintaining flower quality (Doorn & Stead, 1997; Elgimabi, 2011) The substantially higher visual quality score (6.67) and lower wilting percentage (33.33%) observed in the 30 ppm treatment, compared with both lower and higher concentrations, confirm that an optimal silver ion concentration is essential for maximizing these beneficial effects.

The inferior performance of 50 ppm $AgNO_3$, relative to 30 ppm, is consistent with reports of phytotoxic effects at elevated silver ion concentrations (Mijnendonckx et al., 2013; Ohkawa et al., 1999) Excessive silver concentrations may damage vascular tissues, impair water absorption, and accelerate senescence, thereby negating the antimicrobial benefits (Mijnendonckx et al., 2013). The non-significant difference in total water uptake among silver nitrate treatments suggests that the primary mechanism of action of $AgNO_3$ at these concentrations involves qualitative improvement in water movement efficiency rather than quantitative increase in total water absorption.

4.3 Combined Effect of Sucrose and Silver Nitrate

The results of Experiment III confirmed that the combined application of 4% sucrose and 30 ppm $AgNO_3$ produced superior postharvest performance compared with either preservative applied individually. The combined treatment achieved the highest visual quality score (5.00), lowest wilting percentage (50.00%), highest water uptake (35.33 mL), and longest vase life (11+ days). These results support the hypothesis that vase life extension in cut gerbera is governed by the interaction between carbohydrate availability and maintenance of water balance, rather than by either factor alone (Cho & Lee, 1980; Damunupola & Joyce, 2008)

The synergistic action of sucrose and silver nitrate can be explained by their complementary mechanisms: sucrose provides the energy substrate required for respiration, flower opening, and maintenance of cellular metabolism, while silver nitrate preserves xylem functionality by limiting microbial colonization and inhibiting ethylene-mediated senescence (Ohkawa et al., 1999; Yang & Hoffman, 1984) The sustained water uptake observed in the combined treatment, necessitating additional solution replenishment during the experimental period, reflects the continued physiological activity and improved hydration maintained by this treatment. The maintenance of stem firmness and absence of bent-neck symptoms in the combined treatment further demonstrate the efficacy of this preservative combination in addressing the primary postharvest deterioration mechanisms in cut gerbera.

The present findings are consistent with earlier reports demonstrating synergistic effects of combined carbohydrate and antimicrobial treatments in other cut flower species (Cho & Lee, 1980; Halevy & Mayak, 1979) The superiority of the combined treatment over individual treatments highlights the importance of addressing multiple deterioration mechanisms simultaneously in postharvest management of cut flowers. These results have practical implications for commercial floriculture, suggesting that a simple, cost-effective preservative solution containing 4% sucrose and 30 ppm $AgNO_3$ can substantially improve the postharvest performance of cut gerbera flowers under ambient conditions.

CONCLUSION

The present investigation demonstrated that postharvest quality and vase life of cut gerbera (*Gerbera jamesonii*) flowers can be significantly improved through the application of sucrose and silver nitrate preservative solutions. Among the sucrose concentrations evaluated, 4% sucrose was identified as optimal, producing the highest visual quality score and lowest wilting percentage among all sucrose treatments. Among the silver nitrate concentrations tested, 30 ppm $AgNO_3$ was most effective, substantially improving visual quality and reducing wilting relative to the control and other concentrations. The combined application of 4% sucrose and 30 ppm $AgNO_3$ yielded the most favorable postharvest outcomes across all parameters assessed, confirming the synergistic benefits of integrating carbohydrate supplementation with antimicrobial management.

The findings demonstrate that vase life extension in cut gerbera is not governed by a single factor but by the interaction between carbohydrate availability and maintenance of xylem conductivity. The combined preservative solution of 4% sucrose + 30 ppm $AgNO_3$ represents a practical, cost-effective approach for improving postharvest quality and longevity of cut gerbera flowers under ambient commercial conditions. These results provide a scientific basis for recommending this preservative combination to floriculture practitioners and contribute to the broader understanding of postharvest physiology in ornamental cut flowers.

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