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# STRATEGIES FOR IMPROVING VASE LIFE OF CHRYSANTHEMUM CUT FLOWERS: A COMPARATIVE STUDY

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## ABSTRACT
**Background:** Chrysanthemum (Chrysanthemum spp.) ranks as the second most economically important cut flower globally, yet its relatively short vase life limits commercial viability. Chemical preservatives, particularly organic acids, offer potential solutions for extending postharvest longevity.
**Objective:** This study evaluated the effects of citric acid (CA), salicylic acid (SA), and their combinations on fresh weight retention and vase life of chrysanthemum cut flowers over a seven-day period.
**Methods:** Cut chrysanthemum flowers were treated with varying concentrations of CA (100, 200, 300, 550 ppm), SA (100, 200, 300, 550 ppm), and CA+SA combinations (50+50, 100+100, 150+50, 200+100 ppm). Fresh weight was measured daily for seven days, and percentage retention was calculated to assess treatment efficacy.
**Results:** Salicylic acid at 550 ppm demonstrated superior performance with 91% fresh weight retention by day 7, significantly outperforming all other treatments. Citric acid at 300 ppm achieved 61% retention, while the best combination treatment (100+100 ppm CA+SA) yielded 56% retention. Control flowers retained only 36–79% depending on the experimental series.
**Conclusion:** Salicylic acid at 550 ppm is the most effective single treatment for extending chrysanthemum vase life, likely through its multifaceted roles in ethylene inhibition, antimicrobial activity, and stress response modulation. These findings provide practical guidance for commercial floriculture and warrant further investigation into the molecular mechanisms underlying SA's protective effects.

***Keywords:*** *Chrysanthemum, vase life, salicylic acid, citric acid, postharvest physiology, fresh weight retention, cut flowers*

## INTRODUCTION
### 1.1 Economic Importance and Postharvest Challenges
Cut flowers represent precious horticultural products whose commercial value depends critically on maintaining quality and extending vase life. Chrysanthemum (Chrysanthemum spp.) ranks as the second most economically important cut flower worldwide, surpassed only by rose, yet faces significant postharvest limitations due to its relatively short vase life (Kafi & Ghahsareh, 2009). Finding effective methods to increase flower longevity is therefore of paramount importance for the floriculture industry.
The vase life of cut flowers is primarily compromised by two major physiological factors: ethylene-induced senescence and microbial proliferation. Ethylene accelerates senescence in many flower species, while microorganisms cause vascular blockage, reducing water uptake and hastening deterioration (Marry, 2000). Considerable research efforts have been undertaken to address these challenges through the development of floral preservatives and holding solutions.
### 1.2 Chemical Preservatives and Vase Solutions
A floral preservative typically comprises a complex mixture of sucrose (providing respiratory substrate), acidifiers (reducing pH), antimicrobial agents (controlling bacterial growth), and ethylene action or synthesis inhibitors such as silver thiosulfate (STS) or salicylic acid (SA) (Marry, 2000). Adding chemical preservatives to holding solutions is widely recommended to prolong cut flower vase life. All effective holding solutions must contain two essential components: sugar and germicides. Sugar

provides respiratory substrate and enables flowers harvested at the bud stage to open naturally, while germicides control harmful bacteria and prevent plugging of conducting tissues. Among various sugars, sucrose has proven most effective for prolonging vase life, as exogenous application supplies cut flowers with substrates for respiration.

**1.3 Salicylic Acid: A Multifunctional Plant Hormone**

Salicylic acid (SA) is recognised as a potent plant hormone with diverse regulatory roles in plant metabolism. First extracted from willow trees and named after the Latin word Salix, SA plays critical roles in plant defence signalling, ethylene biosynthesis inhibition, and stress tolerance (Popova et al., 1997). SA has been shown to delay ripening and senescence in various horticultural crops, including banana (Srivastava & Dwivedi, 2000), kiwifruit (Zhang et al., 2003), and strawberry (Babalar et al., 2007). In cut flowers, SA treatment has been demonstrated to extend vase life by inhibiting ethylene production (Leslie & Romani, 1988), suppressing microbial growth (Price et al., 2000), and modulating antioxidant enzyme activities (Mehdikhah et al., 2016).

At the molecular level, SA functions as a primary signal in systemic acquired resistance (SAR) and amplifies pathogen-triggered immune responses (Shirasu et al., 1997). It activates defence genes and enhances the sensitivity of plant immune signalling networks (Álvarez, 2000). SA also modulates ion transport, with Harper and Balke (Harper & Balke, 1981) demonstrating concentration-dependent inhibition of $K^+$ absorption in oat roots, suggesting that high SA concentrations may affect cellular water relations in cut flower stems.

**1.4 Citric Acid in Postharvest Management**

Citric acid (CA) is a naturally occurring organic acid widely used in postharvest management as an acidifying agent, antioxidant, flavour enhancer, and preservative. In cut flower applications, CA lowers vase solution pH, thereby reducing microbial proliferation and improving stem conductivity. Studies have shown that CA treatment can extend vase life in various cut flower species by maintaining stem water balance and reducing bacterial populations in the vase solution (Capdeville et al., 2003). Optimal CA concentrations are critical, as excessively high concentrations may induce phytotoxic effects.

**1.5 Combination Treatments**

The integration of diverse organic acids with sugars and antioxidants has emerged as an effective strategy to extend vase life by enhancing water uptake, reducing bacterial contamination, and delaying senescence (Kazemi et al., 2011). Combination treatments of CA and SA may offer synergistic benefits, combining the acidifying and antimicrobial properties of CA with the hormonal and antioxidant activities of SA. However, the optimal ratios and concentrations for such combinations remain poorly defined for chrysanthemum.

**1.6 Study Rationale and Objectives**

Despite extensive research on postharvest management of cut flowers, limited studies have systematically compared the effects of CA, SA, and their combinations at multiple concentrations specifically for chrysanthemum. The present study was therefore designed to: (1) evaluate the effectiveness of CA, SA, and CA+SA combinations at four concentration levels; (2) assess fresh weight retention as an indicator of vase life quality; (3) identify the most effective treatment for commercial application; and (4) contribute to the development of practical, cost-effective postharvest protocols for chrysanthemum floriculture.

## MATERIALS AND METHODS

**2.1 Plant Material**

Chrysanthemum cut flowers (Chrysanthemum spp.) were collected from the locality of Cherai. Healthy specimens of uniform size and at the same developmental stage were selected to minimise variability. Flowers were cut to a standardised stem length and immediately placed in distilled water prior to treatment application.

**2.2 Experimental Site and Conditions**

The experiment was conducted in the 2nd year MSc laboratory under controlled conditions:

- Temperature: 30–35°C
- Relative humidity: 88–92%
- Photoperiod: 12 hours light / 12 hours dark

**2.3 Chemical Reagents**
Analytical-grade salicylic acid (purity 99.5–100%) and citric acid were sourced from certified suppliers. Sucrose (analytical grade) and distilled water (produced in the laboratory) were used throughout. All glassware and materials were thoroughly sterilised prior to use.

**2.4 Experimental Design and Treatments**
The experiment comprised three treatment groups:

**Group 1 – Citric Acid (CA):** Four concentration levels (100, 200, 300, and 550 ppm) plus a distilled-water control (0 ppm).

**Group 2 – Salicylic Acid (SA):** Four concentration levels (100, 200, 300, and 550 ppm) plus a distilled-water control (0 ppm).

**Group 3 – CA + SA Combinations:** Four combination ratios (50+50, 100+100, 150+50, and 200+100 ppm) plus a distilled-water control (0 ppm).

All solutions were prepared by dissolving the respective chemicals in distilled water. A base solution of 4% sucrose (40 g/L) was incorporated across all treatments to provide respiratory substrate.

**2.5 Treatment Preparation**
Tables 1–3 present the amounts of each chemical required to prepare 200 mL of each treatment solution.

***Table 1. Citric Acid (CA) Concentration Preparation Table (per 200 mL distilled water)***

| **Concentration (ppm)** | **Amount in 200 mL Distilled Water (g)** |
|---|---|
| 100 ppm | 0.02 g |
| 200 ppm | 0.04 g |
| 300 ppm | 0.06 g |
| 550 ppm | 0.11 g |

***Table 2. Salicylic Acid (SA) Concentration Preparation Table (per 200 mL distilled water)***

| **Concentration (ppm)** | **Amount in 200 mL Distilled Water (g)** |
|---|---|
| 100 ppm | 0.02 g |
| 200 ppm | 0.04 g |
| 300 ppm | 0.06 g |
| 550 ppm | 0.11 g |

*Note: Analytical-grade SA (purity 99.5–100%) used throughout.*

***Table 3. Salicylic Acid + Citric Acid (SA + CA) Combination Preparation Table (per 200 mL distilled water)***

| **Concentration Combination SA + CA (ppm)** | **Amount in 200 mL Distilled Water (g)** |
|---|---|
| 50 + 50 ppm | 0.01 g + 0.01 g |
| 100 + 100 ppm | 0.02 g + 0.02 g |
| 150 + 50 ppm | 0.03 g + 0.01 g |
| 200 + 100 ppm | 0.04 g + 0.02 g |

*Note: Combinations prepared by dissolving SA and CA separately, then mixing in the stated proportions.*

**2.6 Flower Placement and Observation**
Stems were placed in glass containers containing 200 mL of each treatment solution. The base of each stem was immersed approximately 4–5 cm deep. Containers were covered loosely with parafilm or foil to minimise evaporation while permitting gas exchange. All flowers were maintained under the environmental conditions described in Section 2.2.

**2.7 Parameters Measured**
**Vase Life:** Defined as the number of days from the start of the experiment until the appearance of senescence symptoms, including petal wilting, discolouration, abscission, or bent neck.

**Fresh Weight:** The fresh weight of cut flowers (flower + leafy stem) was measured daily using an analytical balance. Initial fresh weight was recorded immediately before immersion in the treatment solution.
**Photographic Documentation:** Digital photographs (JPEG format) were taken daily to provide visual evidence of treatment effects on flower quality and senescence progression.
**Marketability Assessment:** Marketability was evaluated at regular intervals using a standardised 5-point visual scoring system assessed by a panel of trained judges, evaluating flower freshness, petal colour intensity, turgidity, stem firmness, absence of defects, and leaf colour.

**2.8 Fresh Weight Retention Calculation**
Fresh weight retention was calculated as a percentage of the initial fresh weight to standardise comparisons across treatments with different initial weights:
Fresh Weight Retention (%) = (Weight on Day X ÷ Initial Weight) × 100
Where Weight on Day X is the fresh weight recorded on a specific day and Initial Weight is the fresh weight on Day 1 of the experiment.

**RESULTS**
This study investigated the effects of different vase solutions on the vase life and quality maintenance of cut chrysanthemum flowers. The parameters observed included fresh weight changes over seven days and fresh weight retention percentages. Results are presented separately for each treatment group.
**3.1 Effect of Citric Acid on Fresh Weight**
Table 4 presents the daily fresh weight (g) of chrysanthemum flowers treated with different concentrations of citric acid over seven days. All CA treatments showed a progressive decline in fresh weight over the observation period. The 100 ppm CA treatment maintained the highest absolute fresh weight throughout most of the experimental period, while the 550 ppm treatment showed the steepest decline, reaching 0.83 g by day 7.

***Table 4. Fresh Weight Change (g) in Different Concentrations of Citric Acid (CA)***

| ppm / Day | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 | Day 7 |
|---|---|---|---|---|---|---|---|
| 0 (Control) | 3.31 | 3.26 | 2.92 | 2.62 | 2.05 | 1.44 | 1.20 |
| 100 | 3.83 | 3.27 | 3.21 | 2.84 | 2.05 | 1.95 | 1.91 |
| 200 | 2.69 | 2.66 | 2.43 | 2.22 | — | — | 1.20 |
| 300 | 2.85 | 2.77 | 2.62 | 2.60 | 2.45 | 2.22 | 1.74 |
| 550 | 2.82 | 2.65 | 2.46 | 2.16 | 1.75 | 1.05 | 0.83 |

*Values represent mean fresh weight (g) of chrysanthemum flowers per treatment concentration.*

***Table 5. Citric Acid (CA) – Fresh Weight Retention Summary***

| Concentration | Day 1 (g) | Day 7 (g) | % Retained |
|---|---|---|---|
| 0 ppm (Control) | 3.31 | 1.20 | 36% |
| 100 ppm | 3.83 | 1.91 | 50% |
| 200 ppm | 2.69 | 1.20 | 45% |
| 300 ppm | 2.85 | 1.74 | 61% ✓ Best |
| 550 ppm | 2.82 | 0.83 | 29% |

*✓Best: Highest fresh weight retention among CA treatments. Observation: 300 ppm CA gave the best retention (61%).*

**3.2 Effect of Salicylic Acid on Fresh Weight**
Table 6 shows the daily fresh weight of chrysanthemum flowers treated with different concentrations of salicylic acid. Notably, the 550 ppm SA treatment demonstrated an initial increase in fresh weight from day 1 (2.45 g) to day 3 (3.01 g), indicating active water uptake and turgor maintenance. This treatment maintained substantially higher fresh weights throughout the experimental period compared to all other SA concentrations and the control.

***Table 6. Fresh Weight Change (g) in Different Concentrations of Salicylic Acid (SA)***

| ppm / Day | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 | Day 7 |
|---|---|---|---|---|---|---|---|
| 0 (Control) | 1.27 | 1.29 | 1.53 | 1.57 | 1.45 | 1.25 | 1.01 |
| 100 | 1.87 | 2.02 | 2.23 | 1.65 | 1.57 | 1.47 | 1.35 |
| 200 | 1.64 | 1.68 | 2.07 | 1.88 | 1.78 | 1.64 | 1.34 |
| 300 | 1.72 | 1.57 | 1.35 | 1.10 | 1.04 | 0.64 | 0.60 |
| 550 | 2.45 | 2.76 | 3.01 | 2.88 | 2.50 | 2.37 | 2.24 |

*Values represent mean fresh weight (g) of chrysanthemum flowers per treatment concentration.*

***Table 7. Salicylic Acid (SA) – Fresh Weight Retention Summary***

| Concentration | Day 1 (g) | Day 7 (g) | % Retained |
|---|---|---|---|
| 0 ppm (Control) | 1.27 | 1.01 | 79% |
| 100 ppm | 1.87 | 1.35 | 72% |
| 200 ppm | 1.64 | 1.34 | 82% |
| 300 ppm | 1.72 | 0.60 | 35% |
| 550 ppm | 2.45 | 2.24 | 91% ✓ Best |

*✓ Best: Highest fresh weight retention among SA treatments. Observation: 550 ppm SA significantly outperformed all others (91% retention).*

### 3.3 Effect of CA + SA Combinations on Fresh Weight

Table 8 presents the daily fresh weight data for CA+SA combination treatments. The 150+50 ppm combination began with the highest initial fresh weight (3.00 g) but showed a progressive decline. The 200+100 ppm combination also started high (2.91 g) and maintained relatively stable weights through day 5 (2.36 g). The 100+100 ppm combination demonstrated the most consistent performance over seven days.

***Table 8. Fresh Weight Change (g) in Combinations of Citric Acid and Salicylic Acid (CA + SA)***

| ppm / Day | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 | Day 7 |
|---|---|---|---|---|---|---|---|
| 0 (Control) | 1.83 | 1.77 | 1.71 | 1.54 | 1.31 | 1.28 | 1.22 |
| 50 + 50 | 2.38 | 2.21 | 1.96 | 1.52 | 1.18 | 1.17 | 1.10 |
| 100 + 100 | 2.36 | 2.24 | 2.17 | 2.04 | 1.75 | 1.58 | 1.32 |
| 150 + 50 | 3.00 | 2.65 | 2.63 | 2.24 | 1.71 | 1.54 | 1.23 |
| 200 + 100 | 2.91 | 2.56 | 2.46 | 2.40 | 2.36 | 1.64 | 1.01 |

*Values represent mean fresh weight (g) of chrysanthemum flowers per combination treatment.*

***Table 9. CA + SA Combination – Fresh Weight Retention Summary***

| **Concentration** | **Day 1 (g)** | **Day 7 (g)** | **% Retained** |
|---|---|---|---|
| 0 ppm (Control) | 1.83 | 1.22 | 67% |
| 50 + 50 ppm | 2.38 | 1.10 | 46% |
| 100 + 100 ppm | 2.36 | 1.32 | 56% ✓ Best |
| 150 + 50 ppm | 3.00 | 1.23 | 41% |
| 200 + 100 ppm | 2.91 | 1.01 | 35% |

*✓ Best: Highest fresh weight retention among combination treatments. Observation: 100+100 ppm combo gave the highest retention (56%).*

**3.4 Comparative Summary of Best Treatments**
Table 10 provides a comparative overview of the best-performing treatment in each category.

***Table 10. Summary of Best Performing Treatments – Chrysanthemum***

| **Treatment Type** | **Best Dose** | **% Fresh Weight Retained** |
|---|---|---|
| Citric Acid (CA) | 300 ppm | 61% |
| Salicylic Acid (SA) | 550 ppm | 91% ✓ Overall Best |
| CA + SA Combination | 100 + 100 ppm | 56% |

*✓Overall Best: SA at 550 ppm provided the highest fresh weight retention (91%) among all treatments tested.*

**3.5 Graphical Representation of Fresh Weight Changes**
Figures 1–3 illustrate the fresh weight dynamics over the seven-day experimental period for each treatment group.

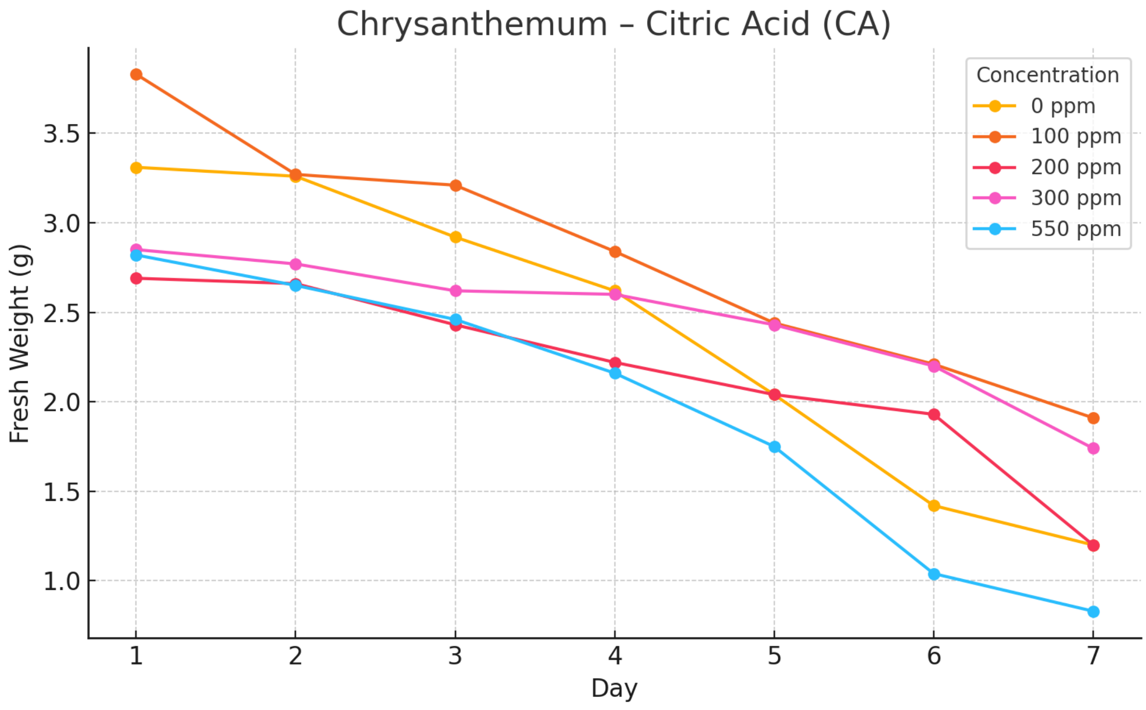


*Figure 1. Fresh weight changes in chrysanthemum flowers treated with different concentrations of Citric Acid (CA) over seven days. The 100 ppm treatment maintained the highest absolute fresh weight, while 550 ppm showed the steepest decline.*

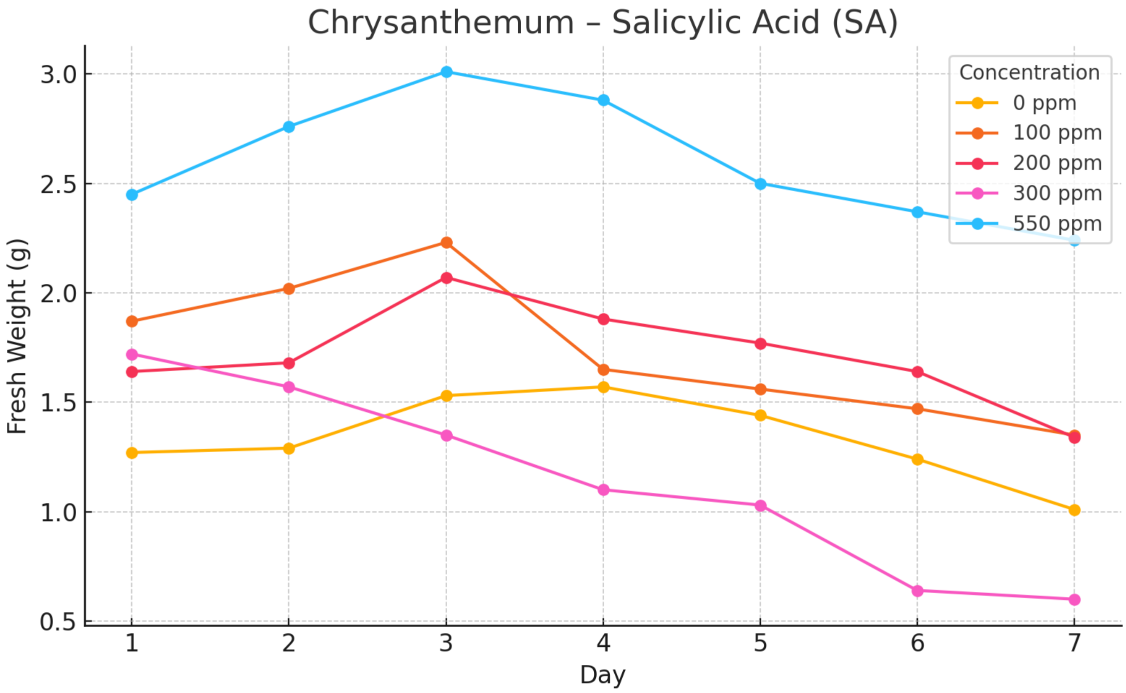


*Figure 2. Fresh weight changes in chrysanthemum flowers treated with different concentrations of Salicylic Acid (SA) over seven days. The 550 ppm SA treatment demonstrated an initial weight increase (days 1–3) before a gradual decline, indicating superior water uptake.*

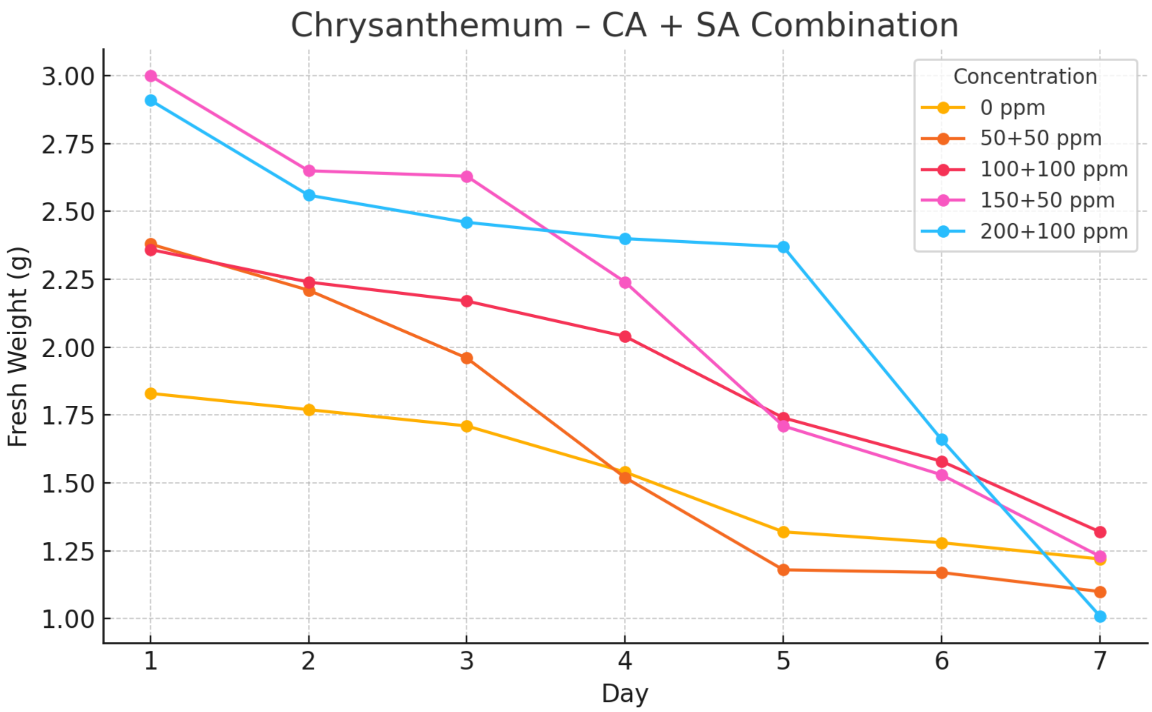


*Figure 3. Fresh weight changes in chrysanthemum flowers treated with CA + SA combinations over seven days. The 100+100 ppm combination showed the most consistent performance with 56% retention by day 7.*

## DISCUSSION

### 4.1 Superiority of Salicylic Acid at 550 ppm

The outstanding performance of SA at 550 ppm (91% fresh weight retention) is consistent with the well-established roles of this phytohormone in delaying senescence and extending postharvest longevity. Budiarto et al. (Budiarto et al., 2022) similarly reported that SA treatment significantly extended the vase life of chrysanthemum cut flowers, corroborating our findings. The initial increase in fresh weight observed in the 550 ppm SA treatment (days 1–3) suggests enhanced water uptake, possibly mediated by SA-induced changes in stomatal conductance and cell membrane permeability.
The mechanism underlying SA's efficacy in cut flower preservation is multifaceted. Leslie and Romani (Leslie & Romani, 1988) demonstrated that SA inhibits ethylene biosynthesis by suppressing 1-aminocyclopropane-1-carboxylic acid (ACC) synthase activity, thereby delaying the ethylene-mediated senescence cascade. Additionally, SA activates antioxidant defence systems, reducing oxidative damage to cellular membranes and prolonging flower freshness (Mehdikhah et al., 2016). The antimicrobial properties of SA further contribute to its preservative effect by reducing vascular blockage caused by bacterial proliferation in the vase solution (Price et al., 2000).

### 4.2 Citric Acid: Optimal Concentration and Mechanism

The superior performance of 300 ppm CA (61% retention) compared to higher concentrations (550 ppm: 29% retention) supports a concentration-dependent biphasic response. At moderate concentrations, CA lowers vase solution pH, creating an unfavourable environment for bacterial growth and improving stem conductivity through enhanced water uptake. This is consistent with findings by Lakmali et al. (Lakmali et al., 2016), who reported that citric acid pulse treatments improved postharvest longevity in gerbera and alstroemeria.
The marked decline in fresh weight retention at 550 ppm CA suggests that excessive acidification may induce phytotoxic effects, potentially disrupting cell membrane integrity or interfering with normal metabolic processes. Ichimura (Ichimura, 1998) noted that colour changes in wilted florets are related to decreased carbohydrate content in flower stalks, and excessive CA may accelerate this process by disrupting carbohydrate metabolism. The finding that 300 ppm CA outperformed both lower and higher concentrations highlights the importance of optimising preservative concentrations for each species.

### 4.3 Combination Treatments: Synergy and Antagonism

The moderate performance of CA+SA combinations (best: 100+100 ppm, 56% retention) compared to SA alone (550 ppm, 91%) suggests that the combination did not produce the anticipated synergistic enhancement. This may reflect competitive interactions between the two compounds at the tested concentrations, where the presence of CA potentially modifies the biological activity of SA. Mehdikhah et al. (Mehdikhah et al., 2016) reported that combinations of salicylic acid, citric acid, and ascorbic acid had varying effects on gerbera vase life depending on concentration ratios, suggesting that optimal synergy requires careful calibration.
The observation that higher combination concentrations (150+50 and 200+100 ppm) resulted in lower retention than the 100+100 ppm combination further supports the hypothesis that concentration balance is critical for combination treatments. Future research should systematically explore a wider range of CA:SA ratios to identify potentially synergistic combinations.

### 4.4 Implications for Commercial Floriculture

The findings of this study have direct practical implications for the cut flower industry. Salicylic acid at 550 ppm represents a highly effective, relatively low-cost, and non-toxic preservative solution for chrysanthemum. SA is a naturally occurring compound in plants and poses minimal environmental concerns compared to synthetic preservatives such as silver thiosulfate (STS). Citric acid at 300 ppm offers an economically viable alternative for situations where SA is unavailable or cost-prohibitive.
The development of easy-to-use treatment protocols based on these findings could benefit florists and consumers by significantly extending the shelf life of commercially important chrysanthemum varieties. Clark et al. (Clark et al., 2010) demonstrated that postharvest longevity varies significantly among cultivars, suggesting that the optimal treatment concentrations identified here should be validated across multiple chrysanthemum cultivars before broad commercial application.

### 4.5 Limitations and Future Directions

Several limitations of this study should be acknowledged. The experiment was conducted under laboratory conditions (30–35°C, 88–92% RH) that may not fully reflect commercial cold-chain storage conditions typically used in floriculture (2–5°C). The relatively high temperature and humidity may have accelerated senescence in control flowers, potentially amplifying treatment effects. Additionally, the study was conducted with a single chrysanthemum variety, limiting the generalisability of findings. Future research should investigate: (1) the efficacy of SA and CA treatments under commercial storage conditions; (2) the molecular mechanisms underlying SA's exceptional performance at 550 ppm; (3) the potential synergy between SA and other preservative components such as sucrose and STS; (4) the cost-effectiveness of SA-based protocols at commercial scale; and (5) the application of these findings to other commercially important chrysanthemum cultivars.

## CONCLUSION

These studies evaluated the effects of various concentrations of Citric Acid (CA), Salicylic Acid (SA), and their combinations on the vase life of cut Chrysanthemum flowers, using fresh weight retention as the primary indicator of postharvest quality over a seven-day period.

The results demonstrated that Salicylic Acid at 550 ppm consistently provided the highest fresh weight retention (91%) across the observation period, indicating enhanced water uptake, delayed senescence, and effective control of vascular blockage. Among Citric Acid treatments, 300 ppm showed the best performance (61% retention), suggesting that moderate acidification supports microbial inhibition and improves stem conductivity without inducing phytotoxicity. The combination treatment of 100 ppm CA + 100 ppm SA resulted in 56% retention — effective but less potent than SA alone.

Control treatments consistently showed lower retention, highlighting the essential role of postharvest preservative solutions in maintaining flower freshness. The findings strongly support the use of Salicylic Acid (550 ppm) as the most effective single-component vase solution for Chrysanthemum, while Citric Acid (300 ppm) and select CA+SA combinations may serve as viable alternatives in commercial floriculture settings.

This research lays a strong foundation for the development of natural, cost-effective vase-life enhancers in floriculture. With further refinement, particularly in combining treatments and validating across cultivars and commercial storage conditions, SA-based protocols hold significant promise for improving the economic viability and sustainability of chrysanthemum production and marketing.

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