







Role of preservative solutions on physiological mechanisms for delaying leaf yellowing in alstroemeria flowers

Função das soluções preservativas nos mecanismos fisiológicos para atrasar o amarelecimento das folhas em hastes florais de Alstroemeria

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ABSTRACT

The primary postharvest challenge for alstroemeria is premature leaf yellowing, which impacts flower quality and diminishes ornamental value. It is hypothesized that using preservative solutions could mitigate this issue. This study aimed to analyze the effects of postharvest preservatives on *Alstroemeria hybrida* 'Akemi' to delay leaf yellowing. Floral stems were collected, standardized, and immersed in different preservative solutions prepared with 6-benzyladenine, gibberellic acid, Floralife Crystal Clear®, Florissant with chlorine and silver thiosulfate. Quality and physiological analyses were conducted, revealing that treatments with gibberellic acid, Florissant with chlorine, and silver thiosulfate demonstrated the highest postharvest vase life. Gibberellic acid and Florissant with chlorine were the most effective in delaying leaf yellowing, preserving total chlorophyll content and maintaining cell integrity and water content. Silver thiosulfate was less effective in preventing leaf yellowing, but it was the only solution capable of preventing perianth abscission. These results suggest gibberellic acid and Florissant with chlorine as the most effective alternatives in delaying leaf yellowing for alstroemerias, in addition to opening possibilities for new research. It is recommended that mixtures involving gibberellic acid and silver thiosulfate be investigated, as well as Florissant with chlorine and silver thiosulfate, as these combinations can enhance the longevity of alstroemeria flowers and leaves during vase life.

Index terms: Cut flower; chlorophyll; postharvest treatments; senescence; vase life.

RESUMO

O principal desafio pós-colheita para Alstroemeria é o amarelecimento precoce das folhas, que compromete a qualidade das flores e reduz o valor ornamental. Hipotetiza-se que o uso de soluções preservativas poderia mitigar esse problema. Este estudo teve como objetivo analisar os efeitos de preservativos pós-colheita em *Alstroemeria hybrida* 'Akemi' para atrasar o amarelecimento das folhas. Hastes florais foram coletadas, padronizadas e imersas em diferentes soluções preservativas preparadas com 6-benziladenina, ácido giberélico, Floralife Crystal Clear®, Florissant com cloro e tiosulfato de prata. Foram realizadas análises de qualidade e fisiológicas, revelando que os tratamentos com ácido giberélico, Florissant com cloro e tiosulfato de prata apresentaram as maiores vidas de vaso. O ácido giberélico e o Florissant com cloro foram os mais eficazes em retardar o amarelecimento das folhas, preservando o teor total de clorofila, mantendo a integridade celular e o conteúdo de água. O tiosulfato de prata foi menos eficaz na prevenção do amarelecimento das folhas, mas foi a única solução capaz de evitar a abscisão do perianto. Esses resultados sugerem o ácido giberélico e o Florissant com cloro como as alternativas mais eficazes no atraso do amarelecimento das folhas em Alstroemeria, além de abrir possibilidades para novas pesquisas. Recomenda-se a investigação de misturas envolvendo ácido giberélico e tiosulfato de prata, bem como Florissant com cloro e tiosulfato de prata, uma vez que essas combinações podem melhorar a longevidade das flores e folhas de Alstroemeria durante a vida de vaso.

Termos para indexação: Flor de corte; clorofila; tratamentos pós-colheita; senescência; vida de vaso.

Introduction

Alstroemeria (*Alstroemeria hybrida* L.) is a globally significant cut flower and ranks as the second most traded in Brazil (Instituto Brasileiro de Floricultura - Ibraflor, 2021). Despite its popularity, it exhibits rapid leaf yellowing during postharvest and commercialization stages, often preceding flower senescence, which significantly reduces its ornamental value (Oliveira et al., 2024; Ponce et al., 2024). Factors contributing to this premature decline include water stress, nutrient deficiencies, suboptimal storage conditions, low temperatures, and sensitivity to ethylene, a hormone gas that accelerates senescence (Toscano et al., 2018; Langroudi et al., 2020). Understanding these physiological disorders is essential for developing strategies to preserve ornamental quality (Amin et al., 2022).

During senescence, irreversible physiological processes occur, leading to flower death. These include fresh weight

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and sugar reserve losses, chlorophyll degradation, increased ethylene production, molecular changes, and electrolyte leakage (Naghiloo et al., 2020; Nasiri et al., 2020; Langroudi et al., 2020). To solve these problems and ensure the quality and extend the vase life of flowers, the use of preservative solutions is recommended (Oliveira et al., 2024).

Several preservative solutions have been evaluated for their efficacy in prolonging the vase life of alstroemerias, without a precise recommendation. Among the most relevant are: 6-benzyladenine (Matak, Hashemabadi, & Kaviani, 2017), gibberellic acid (Yeat, Szydlik, & Łukaszewska, 2012; Kaviya, Lourdasamy, & Vincent, 2021; Ponce et al., 2024), silver thiosulfate (Chanasut et al., 2003; Monya et al., 2021), Florissant 210XC (a commercial solution specific for alstroemerias), and the commercial preservative FloraLife Crystal Clear® (FloraLife, 2023). These solutions primarily function as growth regulators, improving flower quality by inhibiting chlorophyll degradation, reducing water loss, stabilizing respiration, maintaining cell membrane integrity, and reducing ion leakage (Kaviya, Lourdasamy, & Vincent, 2021; Amin et al., 2022). Notably, some preservative solutions, such as silver thiosulfate, also possess antimicrobial properties and regulate ethylene production, reducing flower abscission, senescence, and wilting (Monya et al., 2021).

This study aims to evaluate the physiological effects of different postharvest preservative solutions, especially in preventing the leaf yellowing of floral stems of *Alstroemeria hybrida* 'Akemi'. Additionally, the investigation included analyzing the impact of these solutions on flower condition and the overall quality of the stems, with the objective of identifying the most effective solutions for extending the crop's vase life. To achieve this, several critical questions were formulated: Which preservative solution demonstrates the highest efficacy in prolonging the vase life of *A. hybrida* stems? Which solution best preserves chlorophyll content, thereby delaying the yellowing

process? Which solution effectively stabilizes water content, ensuring cell turgidity and structural integrity?

Material and Methods

In the laboratory, postharvest stages were simulated according to the protocols used by Grupo Reijers, a commercial producer, adjusting the time required for each stage of flower processing.

Stage 1 involved harvesting, transporting the flowers to the laboratory, and arranging them in treatments, lasting 1 day. The flower stems were harvested from the company at commercial standards, with the first flowers showing 30% bloom or color visibility (Girardi et al., 2015). In the processing area, stems were cleaned of extraneous and damaged foliage and buds and recut to 50 cm, then placed in cardboard boxes with the stem bases in artesian well water (pH 6.3). The stems were transported to the laboratory and placed in 500 mL plastic containers with lids perforated six times to hold the stems vertically, totaling 240 stems per experiment. The plastic containers were each filled with 400 mL of their respective preservative solutions, except for silver thiosulfate, which was applied by pulse for 1 hour and then replaced with artesian well water. After that, there was no replacement or filling of the preservative solutions during the experiment.

Eight repetitions per treatment were tested with the following solutions: a) 6-Benzyladenine (BA): 200 mg L⁻¹ (Matak, Hashemabadi, & Kaviani, 2017); b) FloraLife Crystal Clear® Flower Food (CRY): 10 g L⁻¹ (FloraLife, 2023); c) Florissant 210XC (FLO + Cl): 0.05 mL L⁻¹ and chlorine (Cl - 56% available active ingredient) 0.03 g L⁻¹ (commercial standard procedure of Grupo Reijers); d) Gibberellic acid (GA₃): 0.1 mM (Yeat, Szydlik, & Łukaszewska, 2012); e) Silver thiosulfate (STS): 2 mM in pulsing for 1 hour (Chanasut et al., 2003), followed by artesian well water.

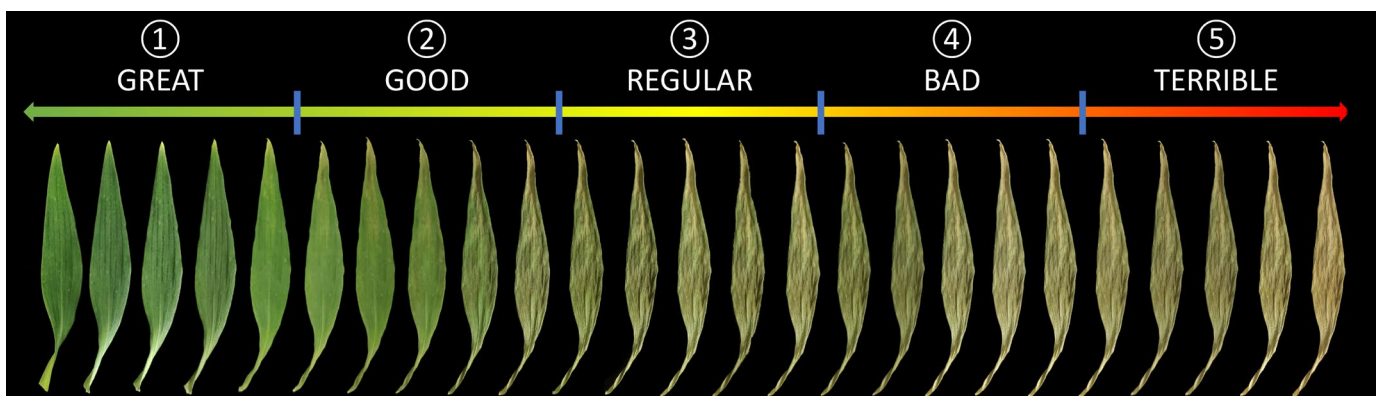


Figure 1: Leaf senescence visual reference scale for *Alstroemeria hybrida* 'Akemi'. 1) 100% green leaves, great quality; 2) 75% green leaves, good quality; 3) 50% green leaves, regular quality; 4) 75% yellowed leaves, bad quality; 5) 100% yellow leaves, terrible quality. Each leaf image represents a postharvest day with the floral stem immersed in artesian well water, totaling 25 days.

All preservative solutions were prepared with 400 mL per container of artesian well water (pH 6.3), without replacement during the experimental period.

Stage 2 involved storing, beginning on the second day after harvest, the stems in a cold chamber at 5 °C for 3 days. These conditions simulate the usual procedure performed by the producer to preserve the flower stems for a maximum of three days until transportation.

Stage 3 simulated transportation, conducted in a refrigerated truck at 7 °C for a maximum of 1 day. The stems were removed from storage and placed in a cold chamber at the transport temperature.

The final Stage 4 simulated the retail conditions: starting on the sixth day, the stems were placed under ambient conditions, with an average temperature adjusted to 22 °C. The experiment ended when 50% of the leaves yellowed or 50% of the flowers exhibited senescence or dropped (Ferrante et al., 2002). A visual reference scale for leaf senescence (Figure 1) and flower senescence (Figure 2) was developed for *Alstroemeria hybrida* 'Akemi' to aid in the assessment.

Daily, at noon, the temperature (°C) and relative humidity (%) of the air in the environment where the stems were located were recorded using the Kasvi thermo-hygrometer model K29-5070H (Figure 3).

Experimental data were collected at the end of each stage. During the consumer evaluation stage, evaluations were

conducted every five days and discontinued once the samples were discarded due to loss of commercial quality.

Vase life

The vase life was assessed by three trained researchers, evaluating twelve stems per treatment counting the number of days from field harvest to the loss of commercial quality, according to Ferrante et al. (2002). This criterion considered the yellowing of 50% of the leaves or the drop/senescence of 50% of the flowers, characterized by the loss of turgor followed by petal wilting.

pH solution

The preservative solution pH was measured with a bench meter (Hanna Edge model HI2002-02). All measurements were performed in triplicate for each treatment.

Relative fresh weight

The relative fresh weight was determined by weighing the stems on an electronic balance (Bioscale model YP-B30001) with a precision of ± 0.1 g. Twelve stems per treatment were evaluated, and the data were used to calculate the relative fresh weight using the following equation: $RFW \% = \frac{FW_{sx}}{FW_{s1}} \times 100$, where FW is the stem fresh weight (g), sx = Stage 1, 2, 3, and 4, and s1 is the stem weight (g) at stage 1 (Jowkar, 2015).

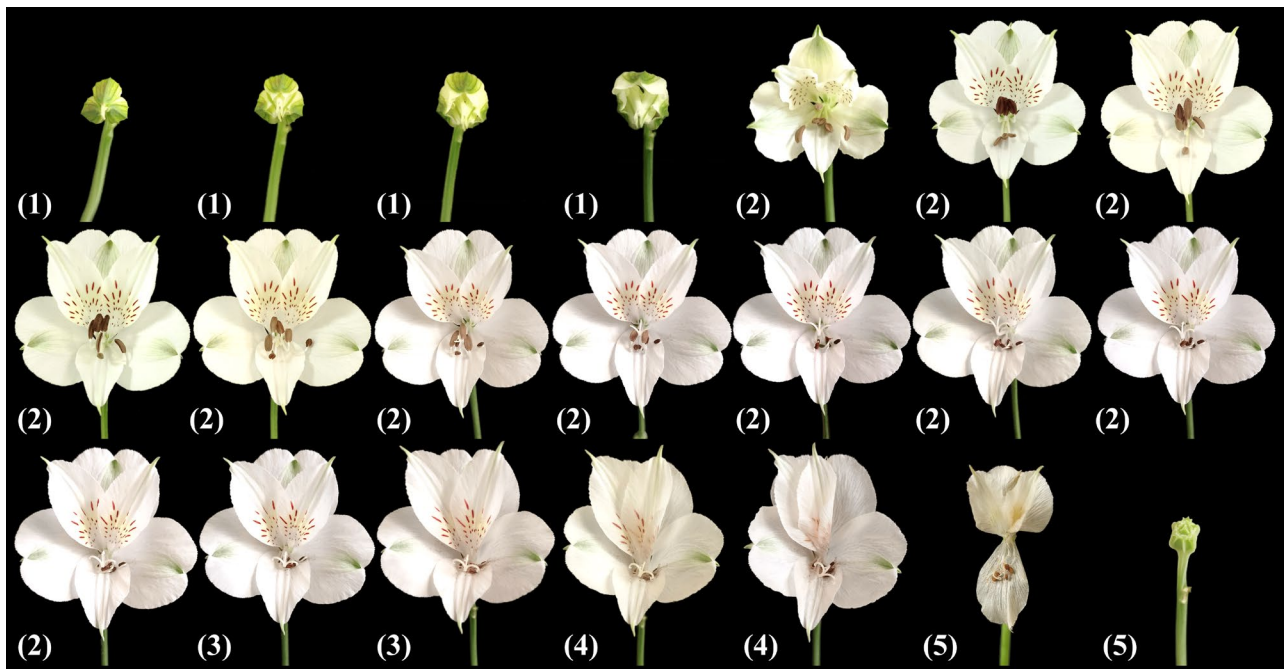


Figure 2: Flower senescence visual reference scale for *Alstroemeria hybrida* 'Akemi'. 1) 100% closed bud, great quality; 2) 25% of the flower with loss of turgor, good quality; 3) 50% of the flower with loss of turgor, regular quality; 4) 75% of the flower with loss of turgor, bad quality; 5) 100% of the flower with loss of turgor or petal drop, terrible quality. Each flower image represents a postharvest day with the floral stem immersed in artesian well water, totaling 21 days.

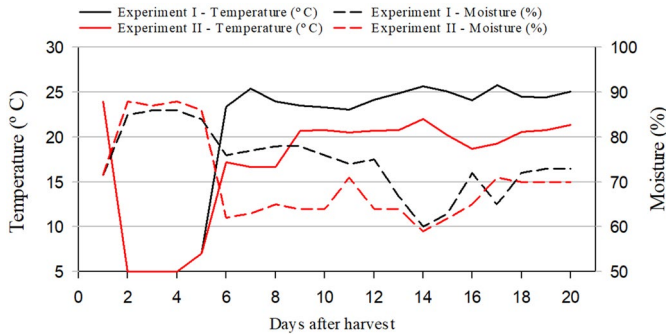


Figure 3: Temperature and relative humidity of the environment.

Total chlorophyll

Total chlorophyll determination on leaves near the inflorescence was conducted using the Falker chlorophyll meter (model CFL1030), resulting in the Falker Chlorophyll Index (FCI). Five leaves were measured per stem, totaling twelve stems per treatment.

Electrolyte leakage

Electrolyte leakage (EL) analysis was performed according to Lutts, Kinet and Bouharmont (1995). From each stem, five sections were taken from leaves near the inflorescence, totaling three stems per treatment. The sections were cut with scissors using a template made of 1 cm² cardboard for standardization. They were then rinsed with distilled water to remove residues, placed in individual vials containing 10 mL of distilled water, and incubated at room temperature (25 °C) on an orbital shaker (Marconi MA140/CFT) at 100 rpm for 24 hours. The electrical conductivity (EC1) was measured using the Quimis meter (model Q405M) after incubation. The samples were then placed in an oven with air circulation (Tecnal model TE-394/3) at 90 °C for two hours, and the second reading (EC2) was taken after the solution had cooled to room temperature. Electrolyte leakage was estimated using the equation: $EL \% = EC1/EC2 \times 100$.

Relative water content

The relative water content was determined following the procedure proposed by Araus and Hogan (1994), collecting five sections of 1 cm² per stem from leaves near the inflorescence, totaling three stems per treatment. The sections were weighed on a digital balance (Shimadzu model ATX224) with a precision of ± 0.0001 g to determine the fresh weight and then placed in tubes with distilled water for 24 hours. The excess water was removed from the sections with a paper towel, and they were weighed again to obtain the turgid weight. The samples were placed in kraft paper envelopes and dried in a microprocessor-controlled drying oven (Quimis model Q317M-12) at 65 °C until they reached a constant weight, then weighed again to obtain the dry weight. The relative water content was determined using the equation: RWC

$\% = (FW-DW)/(TW-DW) \times 100$, where FW is the fresh weight, DW is the dry weight, and TW is the turgid weight.

Experimental design and statistical analysis

Flower stems of *Alstroemeria hybrida* 'Akemi' were harvested from a commercial production field and transferred to the postharvest laboratory. The experiment was conducted in two replicates, following a completely randomized design, with five postharvest preservative solutions and six data collection periods (1, 4, 5, 10, 15, and 20 days after harvest).

The data were subjected to analysis of variance using the F-test ($p \leq 0.05$), considering the average values of the two experiments conducted. When significant, the effects of the products were compared within each evaluation day using Tukey's test with 5% significance. The analyses were performed using R software (R Core Team, 2023).

Results and Discussion

The vase life of alstroemeria floral stems differed significantly depending on the preservative solutions used (Figure 4). The longest vase life was observed with the use of GA₃ (17.2 days), FLO + Cl (17.0 days), and STS (16.7 days). The effectiveness of GA₃ confirms the observations by Oliveira et al. (2024) and Ponce et al. (2024), who achieved a vase life of 23.0 days. Other studies evaluating GA₃ dosages reported durabilities of 13.3 days (Isapareh, Hatamzadeh, & Ghasemnezhad, 2014), 11.7 days (Tiwari et al., 2010), 11.4 days (Yeat, Szydlik, & Łukaszewska, 2012), and 7.3 days (Kaviya, Lourdasamy, & Vincent, 2021), highlighting the importance of using appropriate concentrations to achieve better results. In this study, the use of GA₃ 0.1 mM provided greater vase life for alstroemeria stems, confirming the effectiveness of growth regulators in controlling senescence (Toscano et al., 2018).

GA₃ delays leaf senescence, preserves relative water content, maintains chlorophyll levels, and regulates water absorption. All these factors are critical for extending the postharvest vase life of flowers (Kaviya, Lourdasamy, & Vincent, 2021).

The use of Florissant 210XC with chlorine on alstroemerias is the postharvest procedure employed by the supplier, effectively extending the vase life to 17 days. This confirms the company's observations of approximately 15 days, although Oliveira et al. (2024) managed to maintain commercial quality for up to 22 days. Florissant 210XC is a commercially formulated solution recommended for postharvest treatment of alstroemerias, functioning as an inhibitor of leaf senescence, preventing premature yellowing, restoring hormonal balance, and preserving the color of both flowers and leaves (UFO Supplies, 2023). Additionally, chlorine serves as an antimicrobial agent and enhances stem rigidity due to Ca⁺⁺ ions (Zhao et al., 2019; Timalisina et al., 2023).

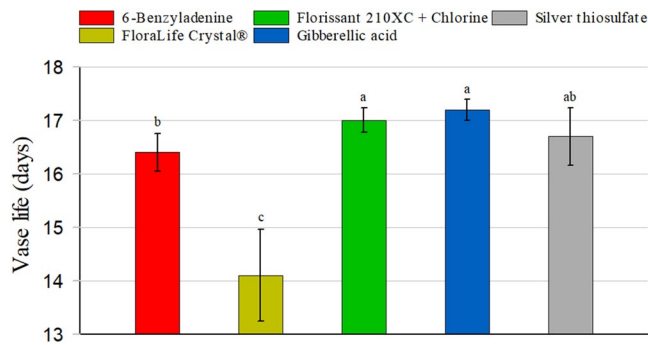


Figure 4: *Alstroemeria hybrida* 'Akemi' floral stems vase life using different preservative solutions. Data are presented as the mean \pm standard error, with $n = 24$. Different letters indicate statistically significant differences (Tukey test, $p \leq 0.05$).

Silver thiosulfate (2 mM solution in a 1-hour pulse) prolonged stem vase life to 16.7 days, like the 16.6 days reported by Chanasut et al. (2003), though less than the 24.0 days obtained by Oliveira et al. (2024). While the vase life was not as extensive as GA_3 and FLO + Cl solutions, this product was effective in preventing petal drops until the end of the experiment. STS was also effective in delaying petal abscission for the 'Rebecca' and 'Samora' cultivars (Wagstaff et al., 2005). STS has been widely used as a floral preservative because the silver ion blocks the harmful effects of ethylene, reducing abscission, senescence, and wilting of flowers, in addition to effectively limiting microbial growth (Shokalu et al., 2021).

The use of 6-benzyladenine (200 mg L⁻¹) extended stem life to 16.4 days, consistent with Matak, Hashemabadi and Kaviani (2017), who observed 15.9 days. BA acts as a growth regulator and has been associated with reducing protein and RNA degradation rates, inhibiting chlorophyll breakdown, stabilizing respiration, maintaining cell membrane integrity, and decreasing ion leakage (Kaviya, Lourdasamy, & Vincent, 2021).

FloraLife Crystal Clear® provided the shortest vase life (14.1 days), as also observed by Oliveira et al. (2024). Although the product is a commercially formulated nutrient solution designed for cut flowers to maintain stem flow and flower hydration (FloraLife, 2023), it was less effective than the other products evaluated.

The visual representation of floral stems treated with preservative solutions during postharvest stages is presented in Figure 5.

Regarding the pH of the solutions (Figure 6), the use of 6-benzyladenine, Florissant 210XC + Cl, gibberellic acid, and silver thiosulfate provided values of pH close to neutral (between 6.1 and 7.1), whereas FloraLife Crystal Clear acidified the solution, resulting in a final pH of 3.5. The rapid leaf yellowing observed in stems preserved with CRY may be related to the acidity, as this product is a nutrient-rich solution, and the pH drop may have caused an imbalance in the flowers' nutrient uptake, accelerating the senescence process. This

negative effect of the solution had previously been observed by Oliveira et al. (2024), though the pH determination had not been conducted to clarify it.

The relative fresh weight of the stems varied throughout the postharvest stages (Figure 7). A similar pattern was observed across treatments, with an upward trend until the 10th day after harvest, followed by a decline. During harvesting, storage, and transportation, the relative fresh weight fluctuated between 100.7% and 103.5%. By the 10th day after harvest, corresponding to the beginning of the commerce phase and the peak of flower bud opening, relative fresh weight ranged from 109.5% to 114.3%. By the end, the most effective treatment for maintaining relative fresh weight was STS (85.9%), followed by BA (85.4%), GA_3 (84.7%), FLO + Cl (81.0%), and CRY (78.0%).

The determination of relative fresh weight helps identify any issues with water and nutrient absorption, allowing for the measurement of stem growth and development and assists in monitoring flower quality over time (Langroudi et al., 2020). The relative fresh weight of alstroemeria stems showed an upward trend while kept at low temperatures until the start of commerce phase. On the 10th day after harvest, with the opening of flower buds, the relative fresh weight values were higher. From the 15th day onward, there was a downward trend, decreasing until the end, with senescence.

The preservative solutions affected the total chlorophyll content in leaves at different postharvest stages of alstroemeria (Figure 8), with more pronounced reductions in stems kept in CRY, showing a 49% decrease between the 10th and 20th day after harvest, which may be related to the solution's pH reduction (Kwartningsih et al., 2021). In contrast, at the end of the commerce period, the stems maintained in GA_3 solutions retained their initial total chlorophyll content, confirming the effectiveness of this growth regulator in preventing the degradation of this molecule (Toscano et al., 2018). The efficiency of GA_3 0.1 mM in maintaining total chlorophyll content and leaf greenness in alstroemeria is supported by the findings of Oliveira et al. (2024), Ponce et al. (2024), and Yeat, Szydlik and Łukaszewska (2012).

Senescence is accompanied by chlorophyll degradation and leaf yellowing in alstroemerias (Oliveira et al., 2024; Ponce et al., 2024). Additionally, as a cut flower, there is reduced water absorption, a decline in turgor, and cell membrane breakdown, contributing to increased leaf chlorosis and loss of ornamental value (Shen et al., 2017). The sensitivity of alstroemerias to ethylene is another factor responsible for chlorophyll loss in leaves, accelerating the tissue senescence rate (Kaviya, Lourdasamy, & Vincent, 2021).

The relative water content of alstroemeria stems differed between treatments applied during postharvest stages (Figure 9). The use of GA_3 and FLO + Cl in preservative solutions resulted in variations of 5.0% and 5.4%, respectively. Conversely, solutions prepared with STS, BA, and CRY showed larger variations and

a downward trend from the 15th day postharvest, corresponding to the commerce phase. There was minor variation in the relative water content of alstroemeria leaves during harvesting, storage, transport, and the beginning of commerce. From the 15th day postharvest, wilting symptoms became apparent, and water loss in the leaves began to intensify. By the 20th day postharvest,

there was a marked reduction in relative water content, with a loss of approximately 15% compared to the initial content. The cutting of floral stems accelerates senescence by limiting their ability to absorb water, causing an imbalance between water absorption and transpiration, loss of cellular turgor, and premature wilting (Liu, Luo, & Liao 2024).

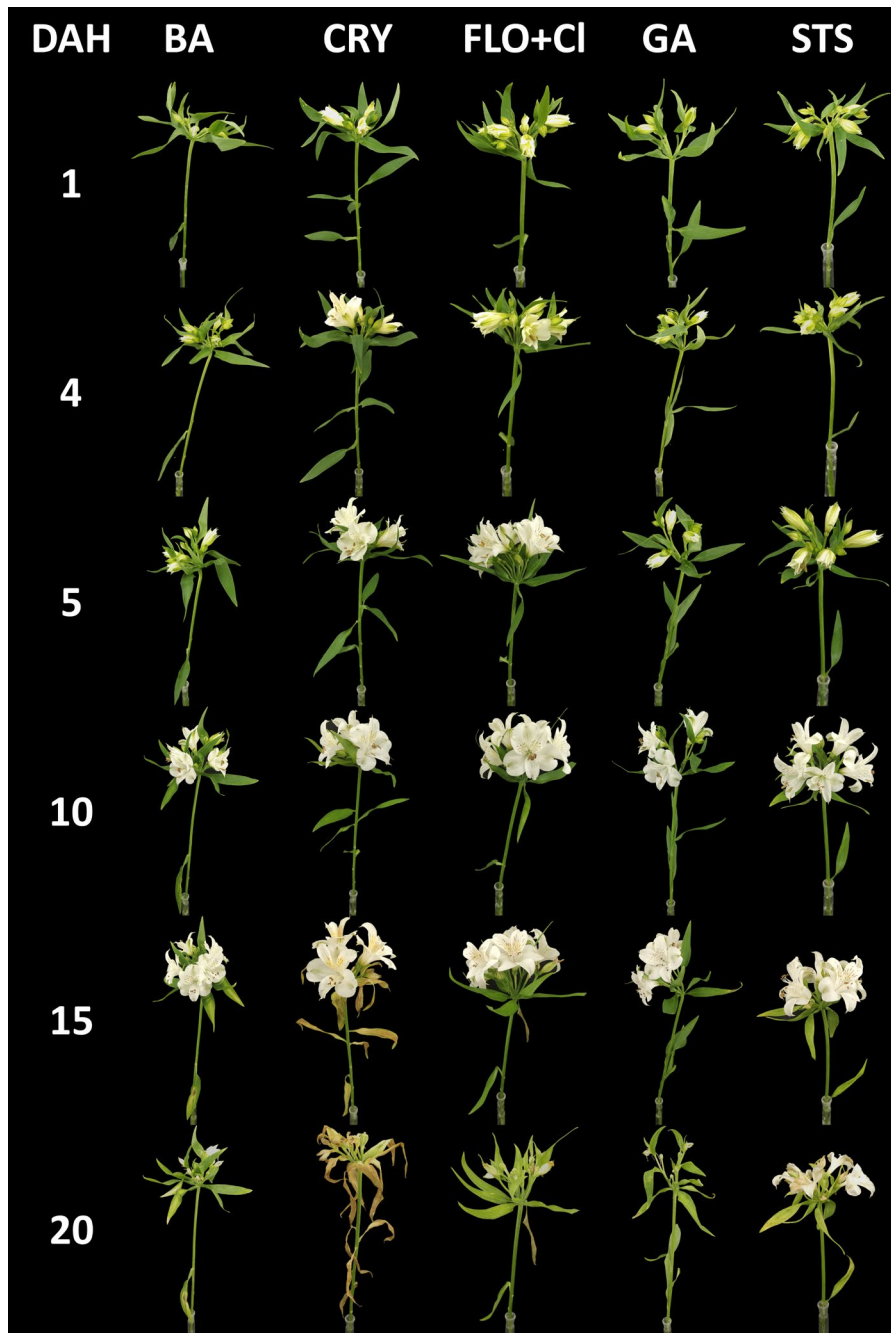


Figure 5: Morphology of *Alstroemeria hybrida* 'Akemi' maintained in different preservative solutions. DAH = days after harvest, BA = 6-benzyladenine, CRY = FloraLife Crystal, FLO+Cl = Florissant 210XC + chlorine, GA = gibberellic acid, STS = silver thiosulfate.

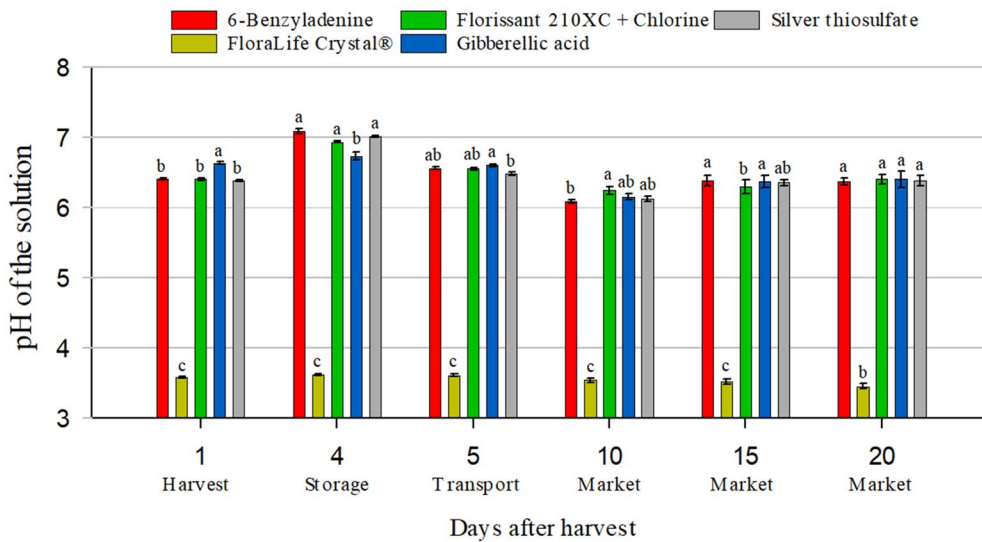


Figure 6: pH of the postharvest preservative solutions. Data are presented as the mean ± standard error, with n = 6. Different letters on the same day after harvest indicate statistically significant differences, as determined by the Tukey test (p ≤ 0.05).

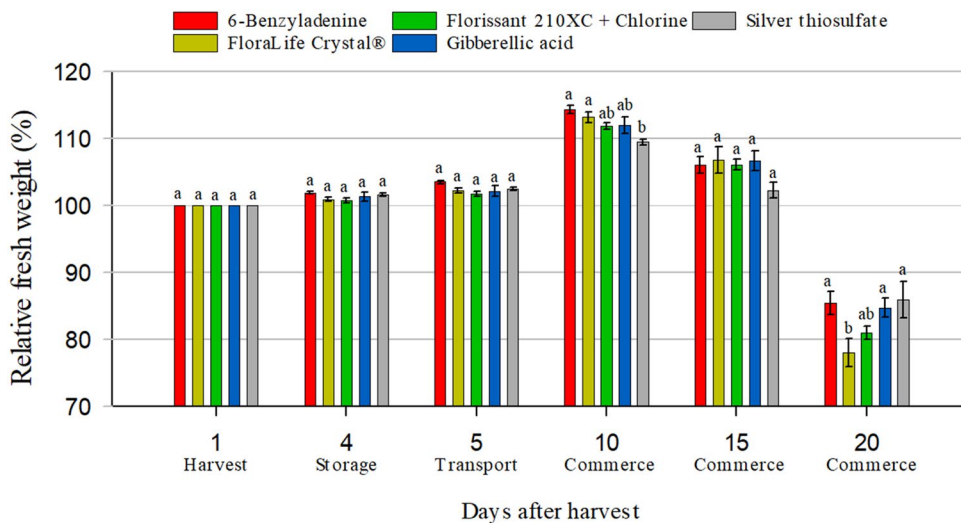


Figure 7: Relative fresh weight of floral stems of *Alstroemeria hybrida* 'Akemi' maintained in different preservative solutions. Data are presented as the mean ± standard error, with n = 24. Different letters on the same day after harvest indicate statistically significant differences from each other, as determined by the Tukey test (p ≤ 0.05).

Electrolyte leakage analysis showed significant differences between treatments at postharvest stages of alstroemeria (Figure 10), with a decreasing trend until the 10th day after harvest, followed by an increase. The lowest electrolyte leakage values were observed on the 10th day after harvest, at the start of commerce phase. Among the tested solutions, FLO + Cl (48.7%) showed the lowest leakage, followed by BA (54.3%), GA₃ (55.1%), CRY (55.7%), and STS (65.4%). By the end of the experiment, the treatments that resulted in the lowest electrolyte leakage, and therefore better-preserved cell membranes, were

GA₃ (62.4%) and FLO + Cl (63.5%), followed by STS (82.4%), BA (91.5%), and CRY (93.5%).

Electrolyte leakage estimates membrane permeability changes in response to environmental stresses, water deficit, growth, development, and genotypic variation, indicating senescence processes (Amin et al., 2022). Preserving the integrity of cell walls reduces electrolyte leakage and extends the longevity of cut flowers like alstroemeria (Kabari & Solimandarabi, 2019). During the harvesting process, electrolyte leakage was higher compared to the storage and transport stages, influenced by the

stress of cutting the stems. However, during storage and transport, when stems were kept at low temperatures, they showed higher values compared to those observed on the 10th day after harvest. Excessive cold causes damage to cell membranes, and the symptoms partly result in electrolyte leakage (Yang et al., 2023). On the 10th day postharvest, at the start of the commercialization period, lower electrolyte leakage values and higher relative fresh weight were observed, highlighting the importance of floral stem hydration for cell integrity. As seen during the senescence process in alstroemeria stems, cell membrane permeability and stability decrease, resulting in electrolyte leakage increasing, besides senescence symptoms accelerating (Kabari & Solimandarabi,

2019). Vase life followed a similar pattern, with higher values observed in treatments with lower electrolyte leakage.

Conversely, higher electrolyte leakage occurred in situations of reduced fresh weight, lower relative water content, and declining total chlorophyll levels, confirming the observations of Langroudi et al. (2020), and Kaviya, Lourdasamy and Vincent (2021), emphasizing the correlation between these physiological responses. For full flower bud opening, high water consumption is required, leading to a significant increase in the relative fresh weight of alstroemeria stems. Subsequently, the flowers accelerate senescence and die because of water loss and mass reduction.

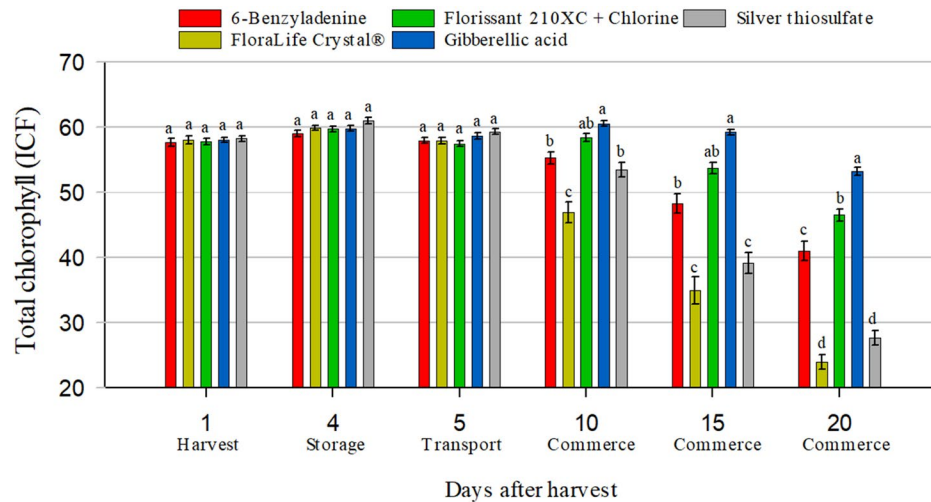


Figure 8: Total chlorophyll content in leaves of *Alstroemeria hybrida* 'Akemi' maintained in different preservative solutions. Data are presented as the mean \pm standard error, with $n = 120$. Different letters on the same day after harvest indicate statistically significant differences from each other, as determined by the Tukey test ($p \leq 0.05$).

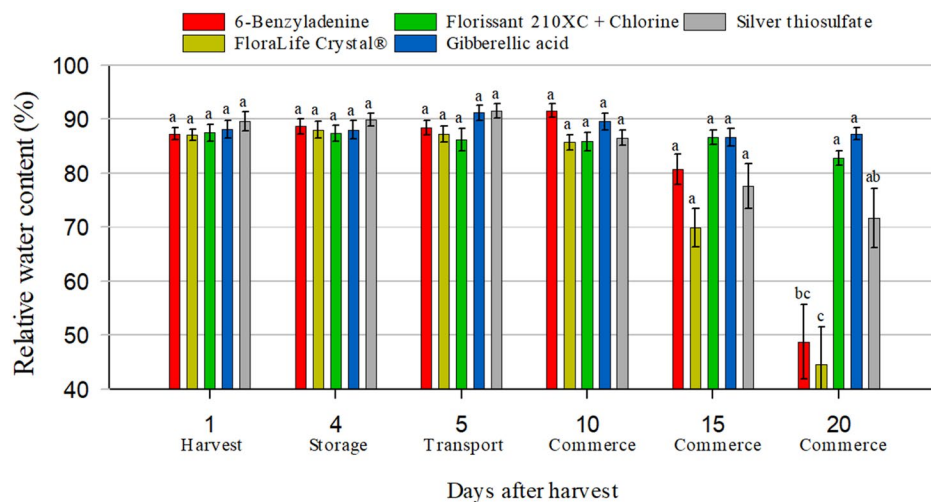


Figure 9: Relative water content in leaves of *Alstroemeria hybrida* 'Akemi' maintained in different preservative solutions. Data are presented as the mean \pm standard error, with $n = 30$. Different letters on the same day after harvest indicate statistically significant differences from each other, as determined by the Tukey test ($p \leq 0.05$).

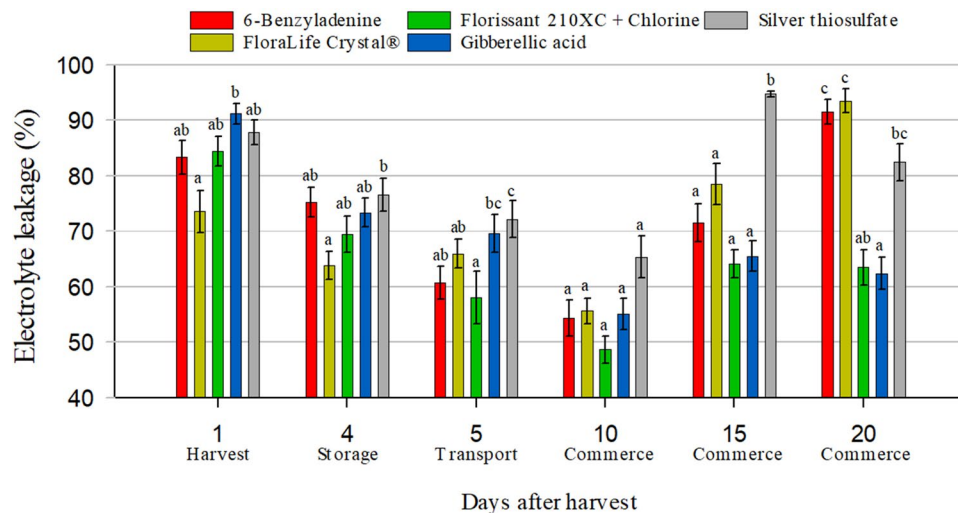


Figure 10: Electrolyte leakage from leaves of *Alstroemeria hybrida* 'Akemi' maintained in different preservative solutions. Data are presented as the mean \pm standard error, with $n = 30$. Different letters on the same day after harvest indicate statistically significant differences from each other, as determined by the Tukey test ($p \leq 0.05$).

The GA3, FLO + Cl, and STS solutions were the most effective in retaining water in the leaves, resulting in greater stem vase life, higher total chlorophyll content, and lower electrolyte leakage. These findings underscore the importance of maintaining adequate water levels in stems and correlate with chlorophyll content, as Shen et al. (2017) noted that reduced water absorption leads to a decline in turgor and, consequently, chlorophyll degradation.

Conclusions

Gibberellic acid (17.2 days), Florissant with chlorine (17.0 days), and silver thiosulfate (16.7 days) extended the vase life of *A. hybrida* stems. Gibberellic acid and Florissant with chlorine best delayed leaf yellowing and preserved total chlorophyll and water content, while silver thiosulfate prevented perianth abscission. Future research should focus on optimizing solution concentrations and combinations of gibberellic acid with silver thiosulfate and Florissant with chlorine with silver thiosulfate to further enhance vase life of alstroemeria cut flowers.

Author contribution

Conceptual Idea: Gama, A.B.N.; Paiva, P.D.O.; Silva, D.P.C.; Methodology design: Gama, A.B.N.; Paiva, P.D.O.; Brito, O.G.; Silva, D.P.C.; Data collection: Gama, A.B.N.; Costa, A.L.; Data analysis and interpretation: Gama, A.B.N.; Paiva, P.D.O.; Brito, O.G.; Paiva, R., and Writing and editing: Gama, A.B.N.; Paiva, P.D.O.; Brito, O.G.

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