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From Senescence Physiology to Postharvest Management: A Review of Strategies for Extending Cut Flower Vase Life

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Abstract

The floriculture industry holds significant economic importance, particularly within the cut flower sector. However, once detached from the mother plant, cut flowers inevitably enter a senescence process that rapidly diminishes their quality and aesthetic appeal. This review, focusing on recent advancements in chemical preservatives, thoroughly investigates the intricate physiological and biochemical mechanisms underlying post-harvest senescence. These mechanisms encompass disruptions in water balance, alterations in macromolecular metabolism, compromises to cell membrane integrity, and fluctuations in endogenous plant hormone levels. Subsequently, this study classifies chemical preservative solutions into distinct categories: pre-treatment, bud-opening, and vase solutions. It further scrutinizes their key components, such as water, carbohydrates, organic acids, antimicrobial agents, plant growth regulators, and soluble inorganic salts. The ultimate objective of this comprehensive overview is to furnish an updated and holistic framework to guide future research and facilitate the development of novel chemical preservation strategies, thereby extending the vase life and enhancing the economic value of cut flowers in the global market.

Keywords: Biochemical changes, Chemical preservatives, Cut flowers, Post-harvest senescence, Vase life.

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1. Introduction: Postharvest Senescence and the Imperative of Enhancing Cut Flower Longevity in the Global Floriculture Industry

Deterioration during the postharvest interval constitutes one of the principal constraints limiting the marketability of harvested plant products, with losses in fresh fruits, vegetables, and ornamental crops frequently exceeding one-third of total yield despite considerable advances in storage and handling technology (Rizzo, 2025). Across these diverse commodities, senescence is consistently associated with a common set of physiological events, including oxidative stress, membrane deterioration, and pigment degradation, which have prompted extensive investigation into exogenous biostimulants capable of delaying quality loss. Recent work has demonstrated, for example, that exogenous arginine mitigates chlorophyll degradation and electrolyte leakage in broccoli florets by activating arginine catabolism and associated polyamine biosynthesis (Malekzadeh et al., 2023), while exogenous dopamine treatment alleviates chilling injury in banana fruit through enhanced glycine betaine accumulation and reactive oxygen species scavenging (Ali et al., 2023). Comparable protective effects have been reported for γ-aminobutyric acid in strawberry, where postharvest decay and membrane lipid peroxidation were substantially reduced (Ali et al., 2025), and for calcium salts and glycine betaine in button mushrooms, both of which delay enzymatic browning and preserve tissue firmness during cold storage (Malekzadeh, Kamrani, et al., 2025; Malekzadeh, Sadeghi, et al., 2025; Siami Khaniki et al., 2025). Collectively, these findings illustrate that postharvest senescence, though manifesting differently across fruit, vegetable, and fungal tissues, shares underlying regulatory mechanisms that can be modulated through targeted exogenous treatment. Cut flowers present a particularly instructive case within this broader context, as their detachment from the mother plant imposes an especially abrupt cessation of water and nutrient supply, resulting in a markedly compressed postharvest window relative to most other horticultural produce (Reid & Jiang, 2012).

Cut flowers, fundamentally defined as detached floral parts (including blooms, flowering stems, and foliage) intended for ornamental arrangements (Reid & Jiang, 2012), constitute a pivotal and rapidly expanding segment of the global floriculture sector. Over the past two decades, the industry has undergone substantial structural development, marked by the consolidation of integrated production and supply chains, the diversification of cultivars, and the emergence of several countries as major regional and international trading hubs (Rashed et al., 2024). China exemplifies this broader trend particularly well: supported by extensive floral biodiversity and considerable investment in cultivar development, the country has established itself as a leading participant in the Asian flower trade, with its floriculture import-export volume reaching approximately 701 million USD in 2021 (Lin, 2025). Comparable expansion has been documented across other major producing and exporting regions, underscoring that the growth of the cut flower trade is a global rather than a geographically isolated phenomenon.

However, the inherent perishability of these valuable horticultural commodities poses a substantial challenge. The physiological and biochemical alterations that ensue immediately following harvest inevitably accelerate senescence, leading to a rapid decline in aesthetic appeal and commercial viability (Jhanji et al., 2025). This swift deterioration necessitates intensive research into effective post-harvest management strategies. Given the escalating diversity of cut flower varieties entering the market, investigations into advanced preservation techniques have become increasingly critical (Rashed et al., 2024).

This review aims to provide a comprehensive analysis of the intricate physiological and biochemical transformations that govern the post-harvest life of fresh cut flowers. Furthermore, it will systematically explore the various categories and constituent components of chemical preservative solutions, delineating their mechanisms of action and overall efficacy. Ultimately, this work seeks to serve as a valuable reference, fostering further research and innovation in the critical domain of cut flower preservation.

2. Physiological and Biochemical Signatures of Post-Harvest Senescence in Cut Flowers

The physiological and biochemical transformations occurring in cut flowers post-harvest are central to understanding and mitigating their eventual decline. These changes collectively orchestrate the process of senescence, significantly impacting the flower's aesthetic and commercial lifespan (Jhanji et al., 2025).

2.1. Disruption of Water Balance

Senescence in cut flowers is primarily manifested through visible alterations such as petal fading, discoloration, dehydration, and the loss of characteristic fragrance. Effective prevention of wilting critically depends on achieving a stable equilibrium between water uptake and transpiration loss, thereby maintaining adequate turgor pressure within the petal cells. Upon their detachment from the parent plant, cut flowers experience a severe disruption in their inherent water balance and a cessation of nutrient supply, which profoundly curtails their vase life and accelerates senescence (Chen, 2024). Indeed, water balance is a paramount determinant of cut flower longevity (van Doorn & Woltering, 2008), and various imbalances in water metabolism are considered primary drivers of senescence (Fanourakis, 2013). Research indicates that enhancing the water absorption capacity, alleviating water stress, and promoting water equilibrium can effectively extend the vase life, as demonstrated in *Paeonia suffruticosa* (Chen, 2024). Furthermore, prolonged water deprivation during storage has been shown to expedite flower opening and stem senescence, drastically shortening the vase life of cut chrysanthemums (Chen, 2024).

The hydrological status of cut flowers is governed by a delicate interplay between water absorption, internal transport, and transpiration. Stem cutting frequently leads to a reduction in water uptake, largely attributable to vascular occlusion, which subsequently contributes to water imbalance and accelerated flower senescence (Manzoor et al., 2024). The primary culprits behind this vascular blockage include plant exudates, microbial proliferation and their metabolic byproducts, air embolisms within the xylem, and particulate matter at the cut surface (Manzoor et al., 2024). Consequently, maintaining optimal water balance within the tissues of fresh cut flowers is an indispensable factor for extending their post-harvest lifespan (Manzoor et al., 2024; Wu et al., 2025).

2.2. Macromolecular Metabolism Shifts

Carbohydrates are not merely fundamental nutrient sources; they also act as crucial signaling molecules that regulate plant growth and developmental pathways (Eveland & Jackson, 2012). The depletion and altered metabolism of macromolecular nutrients during the post-harvest period in fresh cut flowers contribute to an insufficient energy supply, thereby promoting senescence (Jhanji et al., 2025). The breakdown of starch and pectin, alongside the accumulation of hexoses, plays a dual role: it reduces the osmotic potential of petal cells, thereby driving water uptake, increasing turgor pressure, and promoting cell expansion (Beauzamy et al., 2014; van Doorn & van Meeteren, 2003). Beyond nutrition, saccharides are instrumental in facilitating flower opening, regulating stomatal closure (van Doorn, 2001), safeguarding mitochondrial integrity (Kaltaler & Steponkus, 1976), maintaining membrane stability, and generally enhancing the quality of cut flowers (Goszczynska et al., 1990). Supplementation with exogenous saccharides can aid flowers in sustaining their normal energy metabolism and mitigate ethylene sensitivity (Chen, 2024; Fanourakis, 2013); thus, sucrose treatments are a common strategy to extend cut flower vase life (Verlinden, 2004). Studies on *Gladiolus hybridus* (Mayak et al., 1973) and *Dahlia* cut flowers (Ichimura & Azuma, 2022) have confirmed the efficacy of exogenous saccharides in improving flower opening and vase life quality.

In parallel, protein metabolism undergoes significant changes. During the initial stages of anthesis, protein synthesis predominates in petal cells, leading to an increase in protein content. However, as the flower transitions into senescence, the rate of protein synthesis diminishes, and existing proteins are progressively degraded by proteases (Lone et al., 2025), deoxyribonucleases (DNase), and ribonucleases (RNase) (van Doorn & Woltering, 2008). In species such as *Tulipa gesneriana* and roses, protein content exhibits a unimodal curve, initially rising and then declining throughout the senescence process (Kumar et al., 2008). Specifically, during rose cut flower senescence, a reduction in

soluble protein content is observed, while the concentration of free amino acids tends to increase (Chen, 2024).

2.3. Changes in Cell Membrane Integrity and Oxidative Stress

The integrity of cell membranes is a critical determinant of cellular health and resistance to senescence. During the vase life of fresh cut flowers, proline functions as an efficient osmolyte, maintaining cellular homeostasis, scavenging reactive oxygen species (ROS), protecting plant organelles and cellular functional integrity, and enhancing plant adaptation to environmental stress (Kumar et al., 2010; Zhang & Becker, 2015). Fluctuations in proline content can serve as an indicator of the water stress experienced by the plant (Blum, 2017). As flowers age and senesce, the relative permeability of petal cell membranes changes, leading to increased membrane lipid peroxidation. This results in elevated malondialdehyde (MDA) content and increased relative electrical conductivity (Nguyen & Ha, 2026). The accumulation of MDA in petal cells during blooming and senescence signifies intensified lipid peroxidation and consequent membrane damage (Jhanji et al., 2025). A higher degree of cell membrane permeability and senescence correlates with increased relative conductivity (Skutnik et al., 2020).

Furthermore, an imbalance between the generation and detoxification of ROS within petal cells constitutes a significant factor in flower senescence, often leading to oxidative stress (Rogers & Munné-Bosch, 2016; Rogers, 2012). The accumulation of ROS can inflict damage upon cell membrane structures, functional proteins, and nucleic acids, thereby accelerating the senescence process (Ahmad & Tahir, 2016). Consequently, ROS homeostasis is intimately linked with flower aging. Plant cells possess sophisticated enzymatic systems for ROS scavenging, including protective enzymes such as superoxide dismutase (SOD), catalase (CAT), and peroxidase (POD). In the initial phases of flower senescence, the activity of these protective enzymes typically increases, only to decline as the senescence process intensifies (Ahmad & Tahir, 2016).

2.4. Endogenous Hormonal Dynamics

The senescence process in plants is intricately regulated by changes in endogenous plant hormone levels. Plant hormones are potent signaling molecules that orchestrate specific environmental cues within plant cells, regulating physiological responses at low concentrations and coordinating plant growth, development, and differentiation (Lone et al., 2025; Gray, 2004). The physiology of senescence in fresh cut flowers is inextricably linked to the actions of endogenous hormones, including auxin (IAA), gibberellin (GA), cytokinin (CTK), abscisic acid (ABA), and ethylene (ETH). Alterations in their concentrations and balance are closely associated with cut flower senescence. It has been posited that shifts in endogenous hormone levels may be pivotal determinants of cut flower longevity (Lone et al., 2025).

Ethylene: Ethylene is not a universal initiator of senescence, but in ethylene-sensitive species it markedly accelerates the process, with endogenous ethylene levels typically rising as senescence progresses. In ethylene-insensitive species, however, ethylene plays little to no role in triggering or accelerating senescence (Shibuya, 2018). Ethylene can induce changes in cell membrane permeability and composition, leading to leakage of cellular components, ultimately resulting in water loss, petal wilting, and accelerated flower aging. It has been observed that ethylene release in short-lived carnation varieties was 2.5 to 4.5 times higher than in long-lived varieties, supporting its role as a senescence accelerator (Wang et al., 2023).

Abscisic Acid (ABA): ABA is a natural hormone known to promote senescence and abscission (Amin et al., 2026). Its concentration in petals progressively increases as cut flowers open and age (Panavas et al., 1998). A complex interplay exists between ABA and ethylene; in carnations, ABA accumulation precedes ethylene accumulation. Furthermore, exogenous ABA treatment can induce ethylene production in carnations, as evidenced by increased ethylene release post-treatment (Mayak & Dilley, 1976).

Cytokinin (CTK): CTK generally acts as a senescence-retarding hormone. It can decrease respiration rates, promote water absorption, inhibit protein degradation, and prevent the yellowing of leaves in fresh cut flowers and potted plants, thereby delaying senescence (Hönig et al., 2018). Exogenous cytokinin (e.g., 6-BA) has been shown to reduce respiration rates and promote water balance, leading

to an extended vase life for cut flowers (Meir et al., 2007). CTK may also exhibit antagonistic effects with ABA. A higher CTK/ABA ratio is often correlated with slower senescence in cut flowers (Ma et al., 2018).

Gibberellin (GA): Gibberellins promote cell division and elongation, signifying their vital role in plant growth and development. They can also break dormancy, promote stamen differentiation, induce flowering, and delay leaf senescence. Both cytokinin and gibberellin (GA3) levels typically decrease during the senescence process of cut flowers (Castro-Camba et al., 2022).

Auxin (IAA): The effects of auxin (IAA) on various cut flower varieties are ambivalent (Ma et al., 2018). IAA can delay the vase life of *Gladiolus* but accelerate senescence in lilies, orchids, and other flowers. Changes in IAA content during the senescence of different rose varieties exhibit either an increasing or decreasing trend, suggesting species-specific responses (Sun et al., 2021).

In conclusion, the delicate balance and dynamic interplay among these endogenous hormones are closely intertwined with the progression of senescence in cut flowers.

3. Chemical Strategies for Extending Cut Flower Longevity

To counteract the rapid senescence of cut flowers, the floriculture industry employs a diverse array of preservation techniques, encompassing chemical, physical, and genetic approaches. Among these, chemical preservation stands out as the most prevalent method for extending the vase life of fresh cut flowers, owing to its demonstrated efficacy and relative ease of application (Wu et al., 2025). Chemical preservative solutions are broadly categorized into three main types, based on their application timing and specific objectives:

3.1. Pre-treatment Solutions

These solutions are applied immediately after flower harvest and prior to storage, transport, or arrangement in a vase. Their primary objectives include:

Enhanced Water Uptake: Facilitating rehydration and maintaining stem hydration (Wu et al., 2025; Halevy & Mayak, 1981).

Initial Nutrient Provision: Replenishing essential stored food reserves (Wu et al., 2025).

Pathogen Control: Inhibiting microbial growth and preventing vascular blockages.

Ethylene Damage Mitigation: Counteracting the detrimental effects of ethylene during post-harvest handling (Wu et al., 2025).

Through this approach, the senescence process is delayed, ensuring optimal flower quality upon display.

3.2. Bud-Opening Solutions (Pulsing Solutions)

These formulations are designed to accelerate and promote the natural opening of cut flower buds harvested at an immature stage, before retail distribution (Reid, 2005). Bud harvesting is an efficient practice as it shortens the greenhouse growth period, simplifies transport, and reduces economic losses (Halevy & Mayak, 1981). Bud-opening solutions facilitate rapid bud maturation and full bloom by providing necessary nutrients and inhibiting microbial proliferation (Wu et al., 2025).

3.3. Vase Solutions (Holding Solutions)

Vase solutions are utilized by consumers after purchasing flowers, for their ongoing maintenance in a vase. Their principal roles involve:

Nutrient Resupply: Replenishing consumed sugars and other vital compounds (Wu et al., 2025).

Sustained Water Uptake: Maintaining water balance within the stem and petals (Wu et al., 2025).

Microbial Proliferation Inhibition: Preventing solution contamination and vascular occlusion (Manzoor et al., 2024; Wu et al., 2025).

These measures significantly extend the flower's display life in the consumer's home.

4. Key Components and Functions of Chemical Preservative Solutions

The efficacy of preservative solutions in extending the vase life of cut flowers stems from the synergistic interactions of their diverse components, each influencing the flower's water balance and metabolism. Disruption of water balance is a critical factor leading to the termination of vase life. The inclusion of specific compounds in preservative solutions effectively reduces senescence symptoms and prolongs vase life, a phenomenon well-documented across various species such as lilies, roses, carnations, gerberas, and orchids (Chen, 2024). For instance, treating hydrangeas with a solution containing sucrose, 8-HQ, and citric acid has been shown to slow the fresh weight loss of flower

stems, thereby extending vase life (Yang et al., 2021). Similarly, solutions containing GA3, GO, CA, and STS applied to peonies can effectively increase petal relative water content, soluble protein content, and superoxide dismutase (SOD) activity, while reducing the accumulation of free proline and malondialdehyde (MDA), ultimately prolonging the flowering period (Chen, 2024; Zhao et al., 2018).

4.1. The Role of Water in Preservative Solutions

Water quality in preservative solutions significantly impacts the longevity of cut flowers. Three primary types of water are commonly employed:

- Tap Water: Its composition varies regionally, and excessively alkaline tap water may require softening treatment to mitigate adverse effects on cut flowers.
- Deionized or Distilled Water: Due to its high purity, it effectively enhances the vase life of cut flowers and improves the efficacy of preservative solutions (Chen, 2024).
- Microporous Membrane Filtered Water: This is particularly beneficial for cut flowers like roses. Microporous membranes primarily remove air bubbles through filtration and depressurization, substantially reducing air embolisms in vascular bundles (Durkin, 1979).

Generally, tap water has detrimental effects on cut flowers, whereas purer water types tend to extend vase life. Different cut flower species exhibit varying requirements and sensitivities to water quality; carnations, roses, and chrysanthemums are more sensitive, while tulips are relatively less so (Chen, 2024). Key water quality parameters include:

- Acidity (pH): A low pH (3-4) is generally beneficial for cut flowers, effectively inhibiting microbial growth, preventing vascular bundle occlusion in flower stems, and enhancing water uptake capacity, thereby promoting hydration (Carlson & Dole, 2013).
- Total Dissolved Solids (TDS): Total Dissolved Solids (TDS), commonly estimated via electrical conductivity (EC), also influences cut flower senescence, though its effect is highly species-dependent; for instance, the vase life of *Dianthus* and *Zinnia* decreases as EC increases, whereas *Helianthus* remains largely unaffected (Carlson & Dole, 2013).

4.2. Carbohydrates

Saccharidic compounds were among the earliest and most critical components integrated into cut flower preservation (Reid & Jiang, 2012). As the primary nutrient source and energy supplier for cut flowers, carbohydrates profoundly determine the quality of their vase life (Seyed Hajizadeh et al., 2024). For example, a 10% sucrose treatment has been shown to extend the storage period of cut gerberas (Muraleedharan, 2018). Vase solutions containing sucrose, silver nanoparticles, and 8-hydroxyquinoline citrate (8-HQC) can enhance solution uptake and protein content, delay leaf senescence, and reduce MDA accumulation while increasing SOD activity, consequently extending the vase life of cut gerberas (Atefepour et al., 2021).

4.3. Organic Acids

The pH of the cut flower preservative solution significantly influences vase life. For most herbaceous cut flowers (e.g., Dendrobium, Gladiolus, Gerbera), a lower pH environment in the vase solution effectively inhibits microbial proliferation, reduces the incidence of stem vascular blockages, and promotes water absorption by the flower stems, positively impacting cut flower preservation (Halevy & Mayak, 1981; Rattanawisalanon et al., 2003). In a study on Gladiolus cut flowers, citric acid was found to significantly improve the water absorption capacity of flower stems by lowering the vase solution pH, retarding senescence and wilting caused by water loss in petal cells, and notably extending vase life (Khan, 2009). However, for specific cut flower varieties, such as carnations, roses, and hydrangeas, acidic solutions may not always be optimal (Chen, 2024).

4.4. Bactericides

Vascular occlusion in cut flower stems, primarily caused by microbial proliferation in the vase solution, bacterial invasion of xylem vessels, and the secretion of extracellular polysaccharides, is a major factor limiting vase life (Ratnayake et al., 2012). Incorporating bactericides into preservative solutions can effectively inhibit microbial growth and reduce damage to the water balance of flower stems, thereby significantly extending cut flower longevity (Manzoor et al., 2024). 8-Hydroxyquinoline (8-HQ)

and its salts, such as 8-hydroxyquinoline citrate (8-HQC) and 8-hydroxyquinoline sulfate (8-HQS), are widely utilized as bactericides. These compounds exhibit metal-chelating properties, depriving microorganisms of internal iron and copper ions (Bhagwat et al., 2024), and demonstrating potent fungicidal and bactericidal effects. They also help alleviate physiological blockages in stem vascular tissue and enhance water uptake capacity (Marousky, 1969). Furthermore, these compounds function to regulate water pH (i.e., modifying water acidity and alkalinity). By reducing water pH (increasing acidity), they promote water absorption by flower stems and decrease stomatal opening, thereby minimizing transpirational water loss (Marousky, 1971). Studies Meral (2024) by demonstrated that treating carnations with 150 and 250 mg L^{-1} concentrations of 8-hydroxyquinoline citrate (8-HQC) significantly extended the vase life of cut flowers, with the higher concentration (250 mg L^{-1}) producing the most pronounced effect, extending vase life to 12.92 days compared to 10.83 days in the control.

4.5. Plant Growth Regulators

The senescence process of cut flowers, like other vital activities, is governed by hormonal balance. Plant growth regulators achieve extended cut flower vase life by precisely modulating the equilibrium between various hormones. While ethylene (Van Altvorst & Bovy, 1995) and abscisic acid (ABA) (Panavas et al., 1998) are known to accelerate petal senescence, cytokinins (CTK) (Eisinger, 1977) and gibberellins (GA) (Saks & Van Staden, 1992) demonstrate significant senescence-retarding effects. Auxins, conversely, exhibit both delaying and accelerating effects on cut flower senescence, depending on the species (Ma et al., 2018). Cytokinin-type growth regulators, such as kinetin, 6-benzyladenine (6-BA), and isopentenyl adenine (IPA), are extensively used in cut flower preservation practices. These compounds can significantly extend the vase life of various cut flowers, including peonies, carnations, gladiolus, and chrysanthemums (Chen, 2024; Singh & Tiwari, 2021). However, from an industrial development perspective, these substances are often expensive, limiting their widespread application in large-scale production, and much research remains at the laboratory stage.

4.6. Soluble Inorganic Salts

Inorganic salts within preservative solutions can modify the osmotic potential of the solution, regulate the internal and external pressure of petal cells, enabling flower stems to absorb sufficient water and thereby prolonging their vase life. Common inorganic salts utilized in cut flower preservative solutions include potassium, calcium, aluminum, silver, nickel, cobalt, and zinc (Chen, 2024). Studies have shown that $CaCl_2$ in cut flower preservative solutions is beneficial for increasing the fresh weight of cut flowers, promoting flowering, enhancing the activities of SOD, POD, and CAT, delaying the decrease in protein content and relative conductivity, and ultimately extending the vase life of cut flowers (Lou et al., 2021).

5. Future Outlook and Recommendations for Chemical Preservatives

In the cut flower industry, the quality of the final product directly dictates its ornamental value and economic returns. Consequently, the development of highly effective preservative solutions remains a paramount objective (Wu et al., 2025). Propelled by ongoing scientific and technological advancements, novel substances with promising senescence-regulating capabilities are continually being discovered. These include emerging approaches such as nanosilver and plant essential oils, which offer the potential for safer and more sustainable preservation strategies (Bhandari et al., 2026).

Despite the considerable progress achieved in cut flower preservative research, significant challenges persist concerning their widespread industrial implementation. Foremost among these are the prohibitive costs associated with certain chemical solutions and the growing environmental concerns pertaining to potential pollution (Bhandari et al., 2026). Therefore, future research and development efforts must prioritize the creation of chemical preservative solutions that are not only highly efficacious but also cost-effective, non-toxic, and environmentally benign. This dual-pronged approach will be instrumental in both enhancing the quality and extending the vase life of fresh cut flowers, thereby ensuring the long-term sustainability and prosperity of the floriculture industry (El-Sayed et al., 2025).

Conclusion

Cut flower senescence is not driven by a single factor but by the combined breakdown of water relations, carbohydrate and protein metabolism, redox balance, and hormonal signaling. Among these, disruption of stem water balance is arguably the most decisive: vascular occlusion caused by microbial growth, air embolism, and the plant's own wound response restricts water uptake, and the resulting imbalance leads directly to petal wilting and membrane breakdown. At the same time, carbohydrate reserves are depleted, proteins and nucleic acids are degraded by proteases, RNases, and DNases, and reactive oxygen species accumulate faster than antioxidant enzymes such as SOD, CAT, and POD can clear them. The end result is lipid peroxidation, rising MDA levels, and progressively leakier cell membranes.

These changes do not happen independently; they are coordinated by plant hormones. Ethylene and abscisic acid generally push flowers toward senescence and often act together, while cytokinins and gibberellins slow the process down. Auxin sits somewhere in between, sometimes delaying senescence and sometimes accelerating it depending on the species. Because this hormonal balance ultimately determines how quickly a flower ages, it remains one of the more promising, if still underused, targets for postharvest intervention.

Much of current postharvest practice is built around managing these processes through preservative solutions applied at different stages, whether as pulsing treatments, bud-opening formulations, or holding solutions. Sugars replace depleted carbohydrates, bactericides such as 8-hydroxyquinoline salts limit microbial blockage, organic acids lower solution pH to favor water uptake, and inorganic salts help regulate osmotic balance. These treatments work reasonably well across a wide range of species, but cost and environmental impact still limit how widely they can be applied at commercial scale.

Going forward, this problem is likely to be addressed from more than one direction at once. Nanosilver and plant-derived essential oils are already being explored as less toxic, more sustainable alternatives to conventional chemical preservatives. Physical methods, including microporous membrane filtration of vase water and better cold-chain management, can reduce vascular blockage without adding more chemicals to the solution. And in the longer term, breeding or engineering cultivars with reduced ethylene sensitivity or stronger antioxidant capacity could reduce how much postharvest treatment is needed in the first place. None of these approaches is likely to replace the others entirely; combining physiological understanding, better formulations, and genetic improvement will probably do more for the floriculture industry than any single strategy on its own.

References

[1] Rizzo, V. (2025). Sustainable Postharvest Innovations for Fruits and Vegetables: A Comprehensive Review. *Foods*, *14*(24), 4334. https://www.mdpi.com/2304-8158/14/24/4334

[2] Malekzadeh, P., Hatamnia, A. A., & Tiznado-Hernández, M. E. (2023). Arginine catabolism induced by exogenous arginine treatment reduces the loss of green color rate in broccoli florets. *Physiological and Molecular Plant Pathology*, *124*, 101973.

[3] Ali, A. F., Hatamnia, A. A., Malekzadeh, P., Sayyari, M., & Aghdam, M. S. (2023). Exogenous dopamine ameliorates chilling injury in banana fruits by enhancing endogenous dopamine and glycine betaine accumulation and promoting ROS scavenging system activity. *Postharvest Biology and Technology*, *205*, 112521.

[4] Ali, A. F., Hatamnia, A. A., & Malekzadeh, P. (2025). Impact of exogenous GABA treatments on Decay, Senescence, and Antioxidant Capacity in Strawberry Fruit. *Iranian Journal of Postharvest Biology*, *1*(1), 38-47.

[5] Malekzadeh, P., Kamrani, A., Abbasi, Z., & Sadeghi, M. (2025). Glycine betaine treatment

extends the shelf life and retards cap browning of button mushrooms. *Scientific Reports*, *15*(1), 20796. https://doi.org/10.1038/s41598-025-08299-2

[6] Malekzadeh, P., Sadeghi, M., & Sheikhakbari-Mehr, R. (2025). Effect of exogenous melatonin treatment on postharvest quality of apricot fruit through antioxidant metabolism. *Journal of Plant Environmental Physiology*, *78*, 23-39.

[7] Siami Khaniki, M., Rostami-Vartooni, A., & Malekzadeh, P. (2025). Effects of Calcium Salts on Browning of Edible Mushroom Caps. *Iranian Journal of Postharvest Biology*, *1*(1), 27-34.

[8] Reid, M. S., & Jiang, C.-Z. (2012). Postharvest Biology and Technology of Cut Flowers and Potted Plants. In *Horticultural Reviews* (pp. 1-54). https://doi.org/https://doi.org/10.1002/9781118351871.ch1

[9] Rashed, N. M., Memon, S. A., Turki, S. M. A., Shalaby, T. A., & El-Mogy, M. M. (2024). An analysis of conventional and modern packaging approaches for cut flowers: a review article [Review]. *Frontiers in Plant Science*, *Volume 15 - 2024*. https://doi.org/10.3389/fpls.2024.1371100

[10] Lin, D. Y. (2025). International Competitiveness of China's Floriculture Industry. *International Journal of Social Science and Economic Research*, *10*(3), 1030-1046. https://doi.org/https://doi.org/10.46609/IJSSER.2025.v10i03.014

[11] Jhanji, S., Kaur, G., & Chumber, M. (2025). Deciphering flower senescence physiology: advancements in post-harvest storage and preservation techniques for enhancing longevity. *The Journal of Horticultural Science and Biotechnology*, *100*(2), 164-195. https://doi.org/10.1080/14620316.2024.2404039

[12] Chen, S. (2024). Review of recent advances in chemical preservatives for cut flowers. *British Journal of Biology Studies*, *4*(2), 1-8. https://doi.org/https://doi.org/10.32996/bjbs.2024.4.2.1

[13] van Doorn, W. G., & Woltering, E. J. (2008). Physiology and molecular biology of petal senescence. *Journal of Experimental Botany*, *59*(3), 453-480. https://doi.org/10.1093/jxb/erm356

[14] Fanourakis, D., Pieruschka, R., Savvides, A., Macnish, A.J., Sarlikioti, V., and Woltering, E.J. (2013). Sources of vase life variation in cut roses: A review. *Postharvest Biology and Technology*, *78*, 1-15. https://doi.org/https://doi.org/10.1016/j.postharvbio.2012.12.001

[15] Manzoor, A., Bashir, M. A., Naveed, M. S., Akhtar, M. T., & Saeed, S. (2024). Postharvest Chemical Treatment of Physiologically Induced Stem End Blockage Improves Vase Life and Water Relation of Cut Flowers. *Horticulturae*, *10*(3), 271. https://www.mdpi.com/2311-7524/10/3/271

[16] Wu, Y., Zhu, J., Zhang, J., Zhang, Y., Tang, J., Miao, J., Sun, Y., & Zou, J. (2025). Postharvest preservation efficacy and optimization strategies of fresh cut flowers: a meta-analysis and machine learning approach. *Horticulture Research*, *12*(12). https://doi.org/10.1093/hr/uhaf227

[17] Eveland, A. L., & Jackson, D. P. (2012). Sugars, signalling, and plant development. *Journal of Experimental Botany*, *63*(9), 3367-3377. https://doi.org/10.1093/jxb/err379

[18] Beauzamy, L., Nakayama, N., & Boudaoud, A. (2014). Flowers under pressure: ins and outs of turgor regulation in development. *Annals of Botany*, *114*(7), 1517-1533. https://doi.org/10.1093/aob/mcu187

[19] van Doorn, W. G., & van Meeteren, U. (2003). Flower opening and closure: a review. *Journal of Experimental Botany*, *54*(389), 1801-1812. https://doi.org/10.1093/jxb/erg213

[20] van Doorn, W. G. (2001). Role of soluble carbohydrates in flower senescence: A survey. *Acta Horticulturae*, *543*, 179-183. https://doi.org/https://doi.org/10.17660/ActaHortic.2001.543.21

[21] Kaltaler, R. E. L., & Steponkus, P. L. (1976). Factors Affecting Respiration in Cut Roses1. *Journal of the American Society for Horticultural Science*, *101*(4), 352-354. https://doi.org/10.21273/jashs.101.4.352

[22] Goszczynska, D., Itzhaki, H., Borochov, A., & Halevy, A. H. (1990). Effects of sugar on physical and compositional properties of rose petal membranes. *Scientia Horticulturae*, *43*(3), 313-320. https://doi.org/https://doi.org/10.1016/0304-4238(90)90102-K

[23] Verlinden, S., & García, J. J. V. (2004). Sucrose loading decreases ethylene responsiveness in

carnation (Dianthus caryophyllus White Sim) petals. *Postharvest Biology and Technology*, *31*(3), 305-312. https://doi.org/https://doi.org/10.1016/j.postharvbio.2003.09.010

[24] Mayak, S., Bravdo, B., Gvilli, A., & Halevy, A. H. (1973). Improvement of opening of cut gladioli flowers by pretreatment with high sugar concentrations. *Scientia Horticulturae*, *1*(4), 357-365. https://doi.org/https://doi.org/10.1016/0304-4238(73)90020-4

[25] Ichimura, K., & Azuma, M. (2022). Characterization of Petal Senescent Types in Cut Dahlia and Extension of Their Vase Life by Treatment with Silver Thiosulfate Complex Followed by Glucose Plus Germicides. *Horticulturae*, *8*(10), 922. https://www.mdpi.com/2311-7524/8/10/922

[26] Lone, M. L., Haq, A. u., Farooq, S., Parveen, S., Altaf, F., & Tahir, I. (2025). Flower senescence: A comprehensive update on hormonal regulation and molecular aspects of petal death. *Postharvest Biology and Technology*, *220*, 113299. https://doi.org/https://doi.org/10.1016/j.postharvbio.2024.113299

[27] Kumar, N., Srivastava, G. C., & Dixit, K. (2008). Flower bud opening and senescence in roses (Rosa hybrida L.). *Plant Growth Regulation*, *55*(2), 81-99. https://doi.org/10.1007/s10725-008-9263-x

[28] Kumar, N., Pal, M., Singh, A., SaiRam, R. K., & Srivastava, G. C. (2010). Exogenous proline alleviates oxidative stress and increase vase life in rose (Rosa hybrida L. 'Grand Gala'). *Scientia Horticulturae*, *127*(1), 79-85. https://doi.org/https://doi.org/10.1016/j.scienta.2010.09.009

[29] Zhang, L., & Becker, D. (2015). Connecting proline metabolism and signaling pathways in plant senescence [Mini Review]. *Frontiers in Plant Science, Volume 6 - 2015*. https://doi.org/10.3389/fpls.2015.00552

[30] Blum, A. (2017). Osmotic adjustment is a prime drought stress adaptive engine in support of plant production. *Plant, Cell & Environment*, *40*(1), 4-10. https://doi.org/https://doi.org/10.1111/pce.12800

[31] Nguyen, T., & Ha, S. (2026). Advances in the Regulation of Carnation Flower Senescence: Hormonal Control and Emerging Molecular Layers. *Horticulturae*, *12*(3), 277. https://www.mdpi.com/2311-7524/12/3/277

[32] Skutnik, E., Jędrzejuk, A., Rabiza-Świder, J., Rochala-Wojciechowska, J., Latkowska, M., & Łukaszewska, A. (2020). Nanosilver as a novel biocide for control of senescence in garden cosmos. *Scientific Reports*, *10*(1), 10274. https://doi.org/10.1038/s41598-020-67098-z

[33] Rogers, H., & Munné-Bosch, S. (2016). Production and Scavenging of Reactive Oxygen Species and Redox Signaling during Leaf and Flower Senescence: Similar But Different *Plant Physiology*, *171*(3), 1560-1568. https://doi.org/10.1104/pp.16.00163

[34] Rogers, H. J. (2012). Is there an important role for reactive oxygen species and redox regulation during floral senescence? *Plant, Cell & Environment*, *35*(2), 217-233. https://doi.org/https://doi.org/10.1111/j.1365-3040.2011.02373.x

[35] Ahmad, S. S., & Tahir, I. (2016). Increased oxidative stress, lipid peroxidation and protein degradation trigger senescence in Iris versicolor L. flowers. *Physiology and Molecular Biology of Plants*, *22*(4), 507-514. https://doi.org/10.1007/s12298-016-0392-9

[36] Gray, W. M. (2004). Hormonal regulation of plant growth and development. *PLOS Biology*, *2*(9), e311. https://doi.org/https://doi.org/10.1371/journal.pbio.0020311

[37] Shibuya, K. (2018). Molecular aspects of flower senescence and strategies to improve flower longevity. *Breeding Science*, *68*(1), 99-108. https://doi.org/10.1270/jsbbs.17081

[38] Wang, M., Ni, C., Wang, R., Zhong, L., Cheng, Y., Bao, M., & Zhang, F. (2023). Variation in longevity of cut and in planta flowers of potted carnation varieties affected by their relationship with ethylene and water. *Ornamental Plant Research*, *3*(1), 1-11. https://doi.org/10.48130/OPR-2023-0002

[39] Amin, M., Zamani, A. J., Salari, H., Rashidi, M. K., & Faizi, Z. (2026). Impact of Abscisic Acid on Horticultural Crops Senescence: A Review. *International Journal of Agronomy*, *2026*(1), 6020263. https://doi.org/https://doi.org/10.1155/ioa/6020263

[40] Panavas, T., Walker, E. L., & Rubinstein, B. (1998). Possible involvement of abscisic acid in senescence of daylily petals. *Journal of Experimental Botany*, *49*(329), 1987-1997. https://doi.org/10.1093/jxb/49.329.1987

[41] Mayak, S., & Dilley, D. R. (1976). Regulation of Senescence in Carnation (Dianthus caryophyllus): Effect of Abscisic Acid and Carbon Dioxide on Ethylene Production. *Plant Physiology*, *58*(5), 663-665. https://doi.org/10.1104/pp.58.5.663

[42] Hönig, M., Plíhalová, L., Husičková, A., Nisler, J., & Doležal, K. (2018). Role of Cytokinins in Senescence, Antioxidant Defence and Photosynthesis. *International Journal of Molecular Sciences*, *19*(12), 4045. https://www.mdpi.com/1422-0067/19/12/4045

[43] Meir, S., Salim, S., Chernov, Z., & Philosoph-Hadas, S. (2007). QUALITY IMPROVEMENT OF CUT FLOWERS AND POTTED PLANTS WITH POSTHARVEST TREATMENTS BASED ON VARIOUS CYTOKININS AND AUXINS.

[44] Ma, N., Ma, C., Liu, Y., Shahid, M. O., Wang, C., & Gao, J. (2018). Petal senescence: a hormone view. *Journal of Experimental Botany*, *69*(4), 719-732. https://doi.org/10.1093/jxb/ery009

[45] Castro-Camba, R., Sánchez, C., Vidal, N., & Vielba, J. M. (2022). Plant Development and Crop Yield: The Role of Gibberellins. *Plants*, *11*(19), 2650. https://www.mdpi.com/2223-7747/11/19/2650

[46] Sun, X., Qin, M., Yu, Q., Huang, Z., Xiao, Y., Li, Y., Ma, N., & Gao, J. (2021). Molecular understanding of postharvest flower opening and senescence. *Molecular Horticulture*, *1*(1), 7. https://doi.org/10.1186/s43897-021-00015-8

[47] Halevy, A. H., & Mayak, S. (1981). Senescence and Postharvest Physiology of Cut Flowers—Part 2. In *Horticultural Reviews* (pp. 59-143). https://doi.org/https://doi.org/10.1002/9781118060766.ch3

[48] Reid, M. S. (2005). FLOWER DEVELOPMENT: FROM BUD TO BLOOM. *Acta Horticulturae*, *669*, 105-110. https://doi.org/10.17660/ActaHortic.2005.669.12

[49] Yang, H., Lim, S., Lee, J.-H., Choi, J.-W., & Shin, I.-S. (2021). Influence of Solution Combination for Postharvest Treatment Stage on Vase Life of Cut Hydrangea Flowers (Hydrangea macrophylla cv. 'Verena'). *Horticulturae*, *7*(10), 406. https://www.mdpi.com/2311-7524/7/10/406

[50] Zhao, D., Cheng, M., Tang, W., Liu, D., Zhou, S., Meng, J., & Tao, J. (2018). Nano-silver modifies the vase life of cut herbaceous peony (Paeonia lactiflora Pall.) flowers. *Protoplasma*, *255*(4), 1001-1013. https://doi.org/10.1007/s00709-018-1209-1

[51] Durkin, D. J. (1979). Effect of Millipore Filtration, Citric Acid, and Sucrose on Peduncle Water Potential of Cut Rose Flower1. *Journal of the American Society for Horticultural Science*, *104*(6), 860-863. https://doi.org/10.21273/jashs.104.6.860

[52] Carlson, A. S., & Dole, J. M. (2013). Postharvest water quality affects vase life of cut Dendranthema, Dianthus, Helianthus, and Zinnia. *Scientia Horticulturae*, *164*, 277-286. https://doi.org/https://doi.org/10.1016/j.scienta.2013.09.024

[53] Seyed Hajizadeh, H., Bayrami Aghdam, S., Fakhrghazi, H., Karakus, S., & Kaya, O. (2024). Physico-Chemical Responses of Alstroemeria spp. cv. Rebecca to the presence of Salicylic Acid and Sucrose in vase solution during postharvest life. *BMC Plant Biology*, *24*(1), 121. https://doi.org/10.1186/s12870-024-04814-1

[54] Muraleedharan, A., & Joshi, J. L. (2018). Vase life analysis of gerbera (Gerbera jamesonii) cut flowers using different vase solutions var. Arka krishika. *International Journal of Emerging Technologies and Innovative Research*, *5*(7), 113-118. http://www.jetir.org/papers/JETIR1807A15.pdf

[55] Atefepour, E., Saadatian, M., Asil, M. H., & Rabiei, B. (2021). Effect of silver nano particles and 8-hydroxyquinoline citrate on the longer life of cut Gerbera (Gerbera jamesonii) 'Sunway' flowers. *Scientia Horticulturae*, *289*, 110474. https://doi.org/https://doi.org/10.1016/j.scienta.2021.110474

[56] Rattanawisalanon, C., Ketsa, S., & van Doorn, W. G. (2003). Effect of aminooxyacetic acid and sugars on the vase life of Dendrobium flowers. *Postharvest Biology and Technology*, *29*(1), 93-100. https://doi.org/https://doi.org/10.1016/S0925-5214(02)00242-9

[57] Khan, F. N., Yasmin, L., Nasrin, T. A. A., Hossain, M. J., & Golder, P. C. (2009). Effect of sucrose and pH on the vase life of gladiolus flower. *SAARC Journal of Agriculture*, *7*(1), 11-18. http://www.sac.org.bd/archives/journals/sja_v_7_i_1_2009.pdf

[58] Ratnayake, K., Joyce, D. C., & Webb, R. I. (2012). A convenient sample preparation protocol for scanning electron microscope examination of xylem-occluding bacterial biofilm on cut flowers and foliage. *Scientia Horticulturae*, *140*, 12-18. https://doi.org/https://doi.org/10.1016/j.scienta.2012.03.012

[59] Bhagwat, A., Butts, A., Greve, E., Cheung, Y., Melief, E., Gomez, J., Hung, D. T., & Parish, T. (2024). 8-Hydroxyquinoline Series Exerts Bactericidal Activity against Mycobacterium tuberculosis Via Copper-Mediated Toxicity. *ACS Infectious Diseases*, *10*(10), 3692-3698. https://doi.org/10.1021/acsinfecdis.4c00582

[60] Marousky, F. J. (1969). Vascular blockage, water absorption, stomatal opening and respiration of cut 'Better Times' roses treated with 8-hydroxyquinoline citrate and sucrose. *Journal of the American Society for Horticultural Science*, *94*, 223-226.

[61] Marousky, F. J. (1971). Inhibition of vascular blockage and increased moisture retention in cut roses induced by pH, 8-hydroxyquinoline citrate and sucrose. *Journal of the American Society for Horticultural Science*, *96*, 38-41.

[62] Meral, E. D. (2024). Increasing the Vase Life of Cut Carnation (Dianthus caryophyllus L. 'Baltico') by Reducing Xylem Congestion with Some Solutions. *ISPEC Journal of Agricultural Sciences*, *8*(3), 698-708. https://doi.org/https://doi.org/10.5281/zenodo.12745986

[63] Van Altvorst, A. C., & Bovy, A. G. (1995). The role of ethylene in the senescence of carnation flowers, a review. *Plant Growth Regulation*, *16*(1), 43-53. https://doi.org/10.1007/BF00040506

[64] Eisinger, W. (1977). Role of Cytokinins in Carnation Flower Senescence. *Plant Physiology*, *59*(4), 707-709. https://doi.org/10.1104/pp.59.4.707

[65] Saks, Y., & Van Staden, J. (1992). The Role of Gibberellic Acid in the Senescence of Carnation Flowers. *Journal of Plant Physiology*, *139*(4), 484-488. https://doi.org/https://doi.org/10.1016/S0176-1617(11)80499-2

[66] Singh, M., & Tiwari, N. (2021). Thidiazuron outpaces 6-benzylamino purine and kinetin in delaying flower senescence in Gladiolus grandiflora by alleviating physiological and biochemical responses. *Journal of Applied Biology and Biotechnology*, *9*(4), 56-62. https://doi.org/10.7324/JABB.2021.9407

[67] Lou, X., Anwar, M., Wang, Y., Zhang, H., & Ding, J. (2021). Impact of inorganic salts on vase life and postharvest qualities of the cut flower of Perpetual Carnation. *Brazilian Journal of Biology*, *81*.

[68] Bhandari, N., Pun, U. K., & Panth, M. (2026). The efficacy of natural preservatives in extending the vase life of cut flowers. *Science Progress*, *109*(1), 1-26. https://doi.org/https://doi.org/10.1177/00368504261428983

[69] El-Sayed, I. M., El-Ziat, R. A., & Othman, E. Z. (2025). Chitosan and copper nanoparticles in vase solutions elevate the quality and longevity of cut tulips, setting a new standard for sustainability in floriculture. *BMC Plant Biology*, *25*(1), 780. https://doi.org/10.1186/s12870-025-06811-4