International Journal of Biotechnology and Microbiology
www.biotechnologyjournals.com
Online ISSN: 2664-7680
Received: 09-07-2026, Accepted: 09-08-2026, Published: 24-08-2026
Volume 8, Issue 3, 2026, Page No. 70-73

Latest technologies for enhancing the vase life of cut flowers in the floriculture industry

Manju M George*
Department of Botany, Union Christian College (Autonomous) Aluva, Ernakulam District, Kerala, India
DOI: https://doi.org/10.66856/ijbm.2026.8.3.8057

Abstract
The commercial value of cut flowers depends on maintaining water balance, visual quality, and resistance to microbial and physiological deterioration after harvest. Recent work has moved beyond conventional sugar–germicide–ethylene-inhibitor programs toward integrated systems that combine nanomaterials, botanical preservatives, plasma-activated or ozonized water, nanobubbles, controlled lighting, gaseous signaling molecules, and molecular breeding. Most publications reported that pulse treatments generally outperformed conventional vase solutions for short-term preservation, while nanomaterials contributed antimicrobial protection and improved water balance; it also proposed species-specific vase-solution maintenance after an initial pulse treatment. The most credible near-term pathway is therefore not a single "best" additive, but a calibrated, species-specific program that couples sanitation, hydration, ethylene management, antioxidant protection, and appropriate nutrition. Advanced technologies are promising, but their commercial adoption still depends on dose standardization, cultivar-by-treatment validation, worker and environmental safety, cost, and regulatory acceptance.

Keywords: Cut flowers, vase life, postharvest technology, nanotechnology, plasma-activated water, ozone, LED lighting, essential oils, senescence, floriculture

Introduction

Vase life is a key commercial quality trait because it determines customer satisfaction, retail turnover, and the usable period after distribution. Effective postharvest management must preserve hydration while limiting xylem blockage, microbial proliferation, ethylene action, membrane damage, and oxidative deterioration. Recent reviews describe nanotechnology as an emerging platform because nanoparticles can combine antimicrobial activity, ethylene-related effects, antioxidant functions, and improved water uptake. (Keerthana *et al*., 2024) [12]

The technology landscape is now best understood as a set of complementary intervention points. Conventional preservatives remain useful, but their limitations include phytotoxicity, inconsistent performance across species, environmental concerns, and dependence on correct concentration and handling. Recent reviews therefore emphasize biodegradable materials, plant extracts, and other lower-toxicity alternatives, while also recognizing that sustainability claims require direct assessment of efficacy, exposure, persistence, and disposal. (Kumar *et al*., 2024; Jena *et al*., 2025) [9, 13]

Physiological basis for vase-life extension

After harvest, the stem becomes dependent on the vase solution for water uptake and carbohydrate supply. Bacterial growth can obstruct vessels and accelerate water deficit; ethylene can promote petal in-rolling, wilting, and abscission in sensitive species; and reactive oxygen species can damage membranes and pigments. These processes interact, so a treatment that suppresses bacteria but does not maintain water uptake, or a treatment that delays ethylene action but provides no energy source, may produce an incomplete commercial benefit. (Keerthana *et al*., 2024 [12]; Wu *et al*., 2025)

The new technologies target these interacting processes in different ways. Nano-silver and related materials are primarily positioned as antimicrobial and water-balance tools, whereas light treatments act through photosynthetic and antioxidant physiology. Plasma-activated water and ozonized water combine sanitation with redox-active chemistry. Molecular approaches address the upstream regulation of senescence through ethylene perception, signaling, and genetic selection. This mechanistic separation is useful because it clarifies why combinations are often more plausible than isolated treatments. (Keerthana *et al*., 2024; Aalifar *et al*., 2020; Nasibi *et al*., 2024; Raheena *et al*., 2025) [1, 12, 14, 16]

Nanotechnology and nano-enabled vase solutions

Nanomaterials are the most extensively represented emerging technology in the retrieved literature. Reviews identify silver, zinc oxide, chitosan, copper oxide, silica, cerium oxide, carbon nanotubes, and gold nanoparticles as candidate materials with multifunctional antimicrobial, antioxidant, anti-ethylene, and water-uptake effects. (Jena *et al*., 2025) [9] Nano-silver is especially prominent because it can suppress microorganisms and improve postharvest longevity partly by increasing water absorption relative to transpiration. (Keerthana *et al*., 2024) [12]

The technology is evolving in three directions. First, green synthesis uses biological materials to produce nanoparticles, potentially reducing reliance on harsher chemical synthesis routes; phytofabricated silver nanoparticles have been tested in rose vase solutions as a novel antimicrobial treatment. Second, researchers are combining nanoparticles with biopolymers or natural compounds: chitosan with copper nanoparticles has been evaluated in tulips, while nano-silver has been combined with humic acid and Aloe vera gel in carnation. Third, multifunctional systems are being designed to address microbial growth, hydration, oxidative stress, and senescence simultaneously. (Jena *et al*., 2025; Juthee *et al*., 2022; El-Sayed *et al*., 2025; El-Attar *et al*., 2022) [6, 7, 9, 10]

The strongest cross-study synthesis found that nanomaterials have advantages for water balance and antimicrobial protection but should be integrated with other preservatives to provide antioxidant capacity and nutrients. The same analysis proposed an initial nano-enabled pulse followed by a species-specific vase solution, rather than treating nanoparticles as a complete replacement for all other components. (Wu *et al*., 2025) This is an important practical distinction: nanomaterials may be most useful as part of a staged protocol, not as universal standalone preservatives.

Commercial deployment remains constrained by nanoparticle concentration, particle size and stability, cultivar sensitivity, residue and disposal questions, and incomplete environmental risk assessment. A recent review specifically identifies standardization, regulation, and safety assessment as prerequisites for commercialization. (Jena *et al*., 2025) [9]

Essential oils, plant extracts, and biodegradable preservatives

Essential oils and herbal extracts are attractive because they can provide antimicrobial and antioxidant activity while reducing dependence on conventional synthetic preservatives. The retrieved literature includes reviews dedicated to essential oils and primary studies in carnation, Eustoma, narcissus, and other ornamentals. A recent carnation study associated essential-oil treatment with reduced xylem blockage and improved physiological and biochemical status, directly linking a botanical treatment to the hydraulic limitation that commonly shortens vase life. (Kantharaj *et al*., 2018; Gururani *et al*., 2023; Abdossi *et al*., 2018) [8, 11]

Plant-based approaches are not automatically standardized or risk-free. Their composition varies with species, chemotype, extraction method, storage, and concentration; volatile compounds can also cause phytotoxicity or undesirable odor. The useful development path is therefore formulation-based: characterize the active fraction, establish a concentration window, test compatibility with sugars and disinfectants, and evaluate performance under realistic transport and retail conditions. Reviews of eco-friendly preservatives support the direction toward plant-based and biodegradable alternatives but also frame them as components of optimized postharvest management rather than universal substitutes. (Kumar *et al*., 2024) [13]

Plasma, ozone, nanobubbles, and advanced water treatment

Physical and electrochemical water-treatment technologies are among the newest approaches in the literature. Cold atmospheric plasma can generate plasma-activated water containing reactive species that influence microbial load, redox status, and plant tissue physiology. In cut roses, plasma-activated water improved water status, reduced electrolyte leakage, maintained relative water content, lowered malondialdehyde, and supported antioxidant and phenolic responses. (Nasibi *et al*., 2024) [14]

Ozonized water follows a related logic but emphasizes oxidation and microbial control. In cut chrysanthemum, ozonized water reduced bacterial growth and lipid peroxidation, maintained water balance, enhanced antioxidant enzyme activity, and altered phenylpropanoid-related enzyme activity; the reported optimum in that study was an 8-minute water-treatment exposure. (Nasibi *et al*., 2025) [15] Nanobubble and ozone-nanobubble systems extend this concept by improving gas delivery and persistence in the treatment medium; the retrieved literature includes a study applying these systems to Cymbidium cut flowers.

These technologies may reduce chemical residues and provide flexible sanitation, but their performance depends strongly on oxidation intensity, water chemistry, contact time, and cultivar tolerance. They should be evaluated against microbial counts, solution uptake, membrane leakage, petal damage, and worker exposure—not only final vase-life days. The central commercialization question is whether these systems can deliver reproducible treatment intensity at packing-house scale without causing oxidative injury. (Nasibi *et al*., 2024; Nasibi *et al*., 2025; Jena *et al*., 2025) [9, 14, 15]

Controlled lighting and LED technology

Lighting is an underused postharvest control variable. A controlled study of carnation compared white, blue, and red LED spectra and found that blue light delayed senescence and improved vase life relative to red and white light. Blue-light flowers showed lower increases in hydrogen peroxide and malondialdehyde, higher membrane stability, greater antioxidant enzyme activity, delayed carotenoid loss, and higher sugar concentrations. (Aalifar *et al*., 2020) [1]

The implication is not that blue light is universally optimal. Spectral response depends on species, cultivar, irradiance, photoperiod, temperature, and whether leaves remain functional. Recent rose work has also examined red LED light during cold storage and broader comparisons of supplemental light sources. The most useful engineering strategy is likely a controlled-light recipe matched to cultivar physiology and storage temperature, with energy cost and fixture integration included in the economic assessment. (Aalifar *et al*., 2020; Rezai *et al*., 2024; Rezai *et al*., 2023) [1, 17, 19]

Gaseous signaling molecules and combination treatments

Gaseous enrichment of vase solutions is an emerging approach for manipulating redox signaling, ethylene responses, and antioxidant defense. A 2025 study in Matthiola incana tested nitric oxide and hydrogen gas alongside 1-methylcyclopropene, potassium permanganate, chitosan, and other bioactive treatments. The best reported combination—nitric oxide, 1-methylcyclopropene, and chitosan plus sodium nitroprusside—produced a vase life of 25.3 days and improved solution uptake, anthocyanin and carbohydrate accumulation, and delayed senescence. (Asgari Gouraj, 2025) [3]

This study illustrates both the promise and the challenge of combination protocols. Interactions may be synergistic, but a large treatment matrix complicates attribution, optimization, manufacturing, and quality control. Commercial development should use factorial designs and response-surface methods to identify the smallest effective combination, rather than accumulating additives without demonstrating incremental value. (Asgari Gouraj, 2025; Wu *et al*., 2025) [3]

Molecular breeding, omics, peptides, and gene editing

Molecular technologies address vase life before harvest by changing the flower's intrinsic sensitivity to senescence. Ethylene is a central regulator in many ornamentals, and targeted manipulation of ethylene perception or signaling is therefore a recurring strategy. A recent review identifies CRISPR-Cas9 as a potential tool for editing genes involved in floral aging and notes the prospect of delaying petal senescence through targeted changes in ethylene-related pathways. (Raheena *et al*., 2025) [16]

Genomic selection offers a more immediately deployable breeding route where transformation is difficult or commercially unacceptable. In carnation, a 2025 study used 5,412 SNP markers, detected small-effect genomic regions, and concluded that vase life is polygenic. Incorporating top-ranked markers modestly improved prediction accuracy from 0.75 to 0.78, supporting genomic selection while also showing that no single marker is likely to control the trait. (Tavera *et al*., 2025) [20]

Transcriptomics and proteomics can identify senescence markers, candidate pathways, and cultivar-specific response signatures. These data are valuable for discovery, but expression changes must be connected to validated phenotypes and treatment response before they become selection markers or intervention targets. Peptide approaches provide an intermediate strategy between breeding and vase treatment: the NOP-1 peptide derived from the ethylene-signaling regulator EIN2 has been investigated as a way to delay floral senescence in cut flowers. (Yamazaki *et al*., 2024; Yao *et al*., 2021; Casey *et al*., 2023 [4, 23]; Hoppen *et al*., 2019)

Integrating technologies into an industry-ready protocol

The evidence supports a layered protocol rather than a universal preservative. A practical system would begin with harvest maturity, sanitation, rapid hydration, and temperature management; add a short pulse treatment to load antimicrobial or anti-senescence activity; maintain the stems in a species- and cultivar-specific vase solution containing appropriate carbohydrate, disinfectant, and pH control; and use light, gas, ozone, or plasma technologies only where their dose and equipment can be controlled. (Wu *et al*., 2025; Keerthana *et al*., 2024) [12]

The 2025 meta-analysis provides the clearest evidence for this staged logic: pulse treatments performed better than conventional vase solutions for initial extension, but their transient effects required subsequent vase-solution maintenance; nanomaterials improved water balance and antimicrobial protection but benefited from integration with nutrients and antioxidant support; and preservative performance varied by species. (Wu *et al*., 2025)

Validation should use a common minimum dataset: vase life under a predefined visual endpoint; solution uptake; fresh mass; relative water content; bacterial load; membrane leakage; lipid peroxidation; antioxidant enzyme activity; and consumer-relevant traits such as bending, petal browning, color retention, and odor. Trials should include multiple cultivars, realistic cold-chain interruptions, transport vibration, and the intended commercial water quality. Reporting only "days to senescence" makes technologies difficult to compare and obscures trade-offs. (Wu *et al*., 2025; Asgari Gouraj, 2025; Safaei Far *et al*., 2024) [3, 19]

Sustainability, safety, and commercialization gaps

The main sustainability opportunity is to reduce persistent or hazardous preservatives through biodegradable materials, green synthesis, optimized dosing, and water-treatment technologies. The main sustainability risk is replacing a known chemical burden with poorly characterized nanoparticle residues, reactive oxidants, or energy-intensive equipment. Claims of eco-friendliness must therefore be supported by life-cycle thinking, worker exposure assessment, wastewater analysis, and evidence that lower toxicity does not come at the cost of reduced marketable quality. (Kumar *et al*., 2024; Jena *et al*., 2025; Nasibi *et al*., 2024) [9, 13]

The literature also remains heterogeneous. Studies differ in flower species, cultivar, harvest stage, solution composition, temperature, light, endpoints, and visual definitions of vase life. This heterogeneity explains why the same preservative can perform differently across species and why optimization models are valuable. The next generation of work should prioritize standardized protocols, dose–response relationships, replicated multi-cultivar trials, and direct comparisons with current commercial practice. (Wu *et al*., 2025; Tavera *et al*., 2025; Jena *et al*., 2025) [9, 20]

Conclusions

Latest vase-life technologies are converging on four principles: control microorganisms, preserve hydration, regulate senescence signaling, and limit oxidative damage. Nanomaterials and botanical preservatives offer formulation flexibility; plasma-activated water, ozone, and nanobubbles offer advanced sanitation and water-treatment options; LED lighting provides a controllable environmental signal; gaseous molecules and combination treatments target redox and ethylene biology; and genomics, omics, peptides, and gene editing address the intrinsic biology of the flower. (Jena *et al*., 2025; Nasibi *et al*., 2024; Nasibi *et al*., 2025; Aalifar *et al*., 2020; Raheena *et al*., 2025) [1, 9, 14, 15, 16]

The most defensible near-term conclusion is that integrated, species-specific protocols are more promising than single-agent solutions. The strongest current synthesis supports pulse treatment followed by a maintained vase solution, with nanomaterials used for antimicrobial and water-balance functions and complementary components supplying nutrients and antioxidant support. (Wu *et al*., 2025) Longer-term gains will depend on translating molecular mechanisms into validated breeding targets and converting laboratory-scale nano, plasma, ozone, and lighting interventions into safe, reproducible, economical systems for growers, packers, retailers, and consumers.

References

1. Aalifar M, Aliniaeifard S, Arab M, Zare Mehrjerdi M, Dianati Daylami S, Serek M, *et al*. Blue light improves vase life of carnation cut flowers through its effect on the antioxidant defense system. Frontiers in Plant Science,2020:11:511. https://doi.org/10.3389/fpls.2020.00511
2. Abdossi V, Esmaeili F, Kazemi M. Efficiency of essential oils and nano-malate in reduction of ethylene production and extension of vase life of cut *Eustoma grandiflorum* Mariachii cv. Blue flowers. Bangladesh Journal of Botany,2015:44(3):465–468.
3. Asgari Gouraj M. Gaseous enrichment of vase solution enhances vase life and antioxidant capacity in

Matthiola incana cv. 'Lucinda'. Greenhouse Plant Production Journal,2025:2(3):62–73. https://doi.org/10.61882/gppj.2.3.62
4. Casey M, Marchioni I, Lear B, Stead A, Rogers HJ. Using transcriptomics to identify gene markers for flower longevity in dahlias. Acta Horticulturae,2023:1383:237–244. https://doi.org/10.17660/ActaHortic.2023.1383.29
5. Chen CX, Jiang YH, Sun XM, Zhou XF, Xu YJ, Ma C, *et al*. How can physiological and genetic approaches on vase life help rose breeders and producers? Acta Horticulturae,2023:1368:1–8. https://doi.org/10.17660/ActaHortic.2023.1368.1
6. El-Attar ABESE, Sakr WRA. Extending vase life of carnation flowers by postharvest nano silver, humic acid and Aloe Vera gel treatments. Ornamental Horticulture,2022:28(1):67–77. https://doi.org/10.1590/2447-536X.v28i1.2407
7. El-Sayed IM, El-Ziat RA, Othman EZ. 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,2025:25:780. https://doi.org/10.1186/s12870-025-06811-4
8. Gururani MA, Atteya AK, Elhakem A, El-Sheshtawy ANA, El-Serafy RS. Essential oils prolonged the cut carnation longevity by limiting the xylem blockage and enhancing the physiological and biochemical levels. PLOS ONE,2023:18(3):0281717. https://doi.org/10.1371/journal.pone.0281717
9. Jena SS, Savaliya DK, Chetia P, Tomar R, Bhagat A, Nagaraju D, *et al*. Nanotechnology in post-harvest management of ornamentals: Innovations beyond conventional preservatives. International Journal of Research in Agronomy,2025:8(9):825–831. https://doi.org/10.33545/2618060X.2025.v8.i9l.3861
10. Juthee SA, Karim MM, Polash MAS, Fakir MSA, Hossain MA. Phytofabricated silver nanoparticles (AgNPs) applied in vase solution as a novel anti-microbial agent for enhancing the vase-life of cut-rose flower. Journal of Bangladesh Agricultural University,2022:20(2):133–140. https://doi.org/10.5455/JBAU.140222
11. Kantharaj Y, Madaiah D, Hemla Naik B, Sadashiva Nadukeri S, Devaraju. Significance of essential oils and herbal extracts on vase life of cut flowers: A review. Journal of Pharmacognosy and Phytochemistry,2018:7(3S):252–256.
12. Keerthana M, Beaulah A, Rajadurai KR, Venkatesan K, Anitha T, Ravi R, *et al*. Nanotechnology in floriculture: Extending vase life and improving postharvest quality. Plant Science Today,2024:11(4):1–10. https://doi.org/10.14719/pst.5151
13. Kumar M, Kumar R, Motla R, Sharma M, Shukla D, Kaushik K, *et al*. Innovative eco-friendly approaches to enhance the vase life of cut flowers: A comprehensive review. Journal of Advances in Biology & Biotechnology,2024:27(12):36–45. https://doi.org/10.9734/jabb/2024/v27i121753
14. Nasibi F, Farahmand H, Noori H, Mousavi Shahabi Z. Cold atmospheric pressure plasma as eco-friendly technology prolonged the vase life and improved the quality of cut rose flowers. Scientia Horticulturae,2024:327:112829. https://doi.org/10.1016/j.scienta.2023.112829
15. Nasibi F, Noori H, Farahmand H, Mousavi Shahabi Z. Ozonized water as a novel technology improves postharvest quality and longevity of *Dendranthema × grandiflora* cut flowers. Plant Biosystems,2025:159(6):1569–1579. https://doi.org/10.1080/11263504.2025.2543869
16. Raheena KT, Uthup TK, Athira PV, Prabhakaran D, Vinod A, Rekha K, *et al*. Manipulation of floral senescence through gene editing: Prospects for ornamental and cut flowers. Plant Growth Regulation,2025:105:1911–1926. https://doi.org/10.1007/s10725-025-01391-7
17. Rezai S, Nikbakht A, Zarei H, Sabzalian MR. Physiological, biochemical, and postharvest characteristics of two cut rose cultivars are regulated by various supplemental light sources. Scientia Horticulturae,2023:313:111934. https://doi.org/10.1016/j.scienta.2023.111934
18. Rezai S, Sabzalian MR, Nikbakht A, Zarei H. Red LED light improved the vase life of cut rose flowers during cold storage. Postharvest Biology and Technology,2024:210:112752. https://doi.org/10.1016/j.postharvbio.2023.112752
19. Safaei Far A, Mousavi-Fard S, Rezaei Nejad A, Shahbazi F, Ahmadi-Majd M, Fanourakis D. Nano silver and melatonin effectively delay the senescence of cut carnation flowers under simulated vibrational stress. The Journal of Horticultural Science and Biotechnology,2024:99(5):597–608. https://doi.org/10.1080/14620316.2024.2334306
20. Tavera HH, Losert D, Boxriker M, Boehm R, Zenke-Philippi C. Genetic architecture and genomic prediction of vase life in carnation. Frontiers in Plant Science,2025:16:1673111. https://doi.org/10.3389/fpls.2025.1673111
21. Wu Y, Zhu J, Zhang J, Zhang Y, Tang J, Miao J, *et al*. Postharvest preservation efficacy and optimization strategies of fresh cut flowers: A meta-analysis and machine learning approach. Horticulture Research,2025:12(12):227. https://doi.org/10.1093/hr/uhaf227
22. Yao J, Li R, Cheng Y, Li ZG. A combined transcriptomic and proteomic analysis of chrysanthemum provides new insights into petal senescence. Planta,2022:255(1):22. https://doi.org/10.1007/s00425-021-03808-9
23. Yamazaki K, Kitamura R, Suzuki T, Kurokura T, Yamane K. Transcriptome analysis highlights the molecular mechanisms associated with the senescence of florets in gladiolus. The Horticulture Journal,2024:93(1):76–88. https://doi.org/10.2503/hortj.QH-079