

Recent Trends in Enhancing Vase Life in Tropical Cut Flowers: A Review

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Abstract
Anthurium, *Heliconia*, orchids, *Strelitzia* and other Zingiberales are tropical cut flowers that are valued for their unique inflorescences, vibrant colours and suitability for high-end floral markets. However, their postharvest performance is limited by rapid water imbalance, microbial blockage, carbohydrate depletion, oxidative stress, chilling injury and species-specific senescence responses. Recent advances in vase-life improvement are reviewed, with emphasis on findings from tropical flowers. This is distinguished from the wider field of cut-flower research. The literature reveals a trend from single purpose preservative solutions to integrated systems that cover hydration, carbohydrate supply, antimicrobial action, antioxidant protection and temperature management. Recent developments include low-cost holding solutions, salicylic acid and ascorbate treatments, essential oils and plant extract, biostimulants, modified atmosphere packaging, waxing, nanomaterials and image-based quality monitoring. Research specific to the tropics indicates that water relations and chilling sensitivity are especially important in *Anthurium* and *Heliconia*, whereas orchids respond strongly to microbial control, modified atmospheres and antioxidant strategies. Natural products and nanomaterials are promising, but their commercial adoption requires standardised doses, toxicological assessment, residue evaluation and validation under supply chain conditions. Future progress will rely on cultivar-specific protocols, combination treatments, non-destructive sensing, life-cycle assessment, and data-driven optimisation.

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1. Introduction

Tropical cut flowers have a significant niche in ornamental horticulture because they have exotic forms and a long-lasting visual appeal, which is very different from temperate species. Examples of commercial importance are *Anthurium andraeanum*, *Heliconia* spp., *Strelitzia reginae*, *Dendrobium* and *Mokara* orchids and other Zingiberales. Yet, the morphological and physiological characteristics that confer market value can pose challenges for postharvest handling. Large bracts, fleshy tissues, heterogeneous vascular anatomy, high surface area, and sensitivity to low temperature may contribute to the rapid decline of display quality after harvest (Buanong & Uthairatanakij, 2020; Costa *et al*., 2021; Malakar *et al*., 2023) [5, 8, 19].

Vase life is not one physiological trait. The period for which a cut flower is commercially acceptable with adequate turgor, colour, form, stem integrity and freedom from microbial decay. Water balance is often the proximate determinant of quality, but interacts with carbohydrate status, membrane stability, oxidative metabolism, ethylene sensitivity and microbial proliferation. Hence, the latest research has moved beyond the traditional sugar and germicide solutions to integrated postharvest systems (Costa *et al*., 2021; Wu *et al*., 2025) [8, 34].

This review presents recent trends in extending the vase life of tropical cut flowers. (a) water relations and holding solutions, (b) carbohydrate, antioxidant and antimicrobial management, (c) natural products and biostimulants, (d) packaging, storage and physical treatments, (e) nanotechnology and digital assessment, and (f) research priorities for sustainable commercialisation. The discussion is based largely on recent studies, but where necessary, earlier foundational ideas are introduced to make sense of, and interpret, current practices.

2. Physiological Targets for Vase-Life Extension

2.1. Water Relations and Hydraulic Failure

Water stress is the main cause of wilting and loss of ornamental value. When stems are cut off, air embolism, microbial growth, or accumulation of materials at the cut surface can reduce the xylem conductivity. If transpiration exceeds water uptake, bracts, petals and leaves will lose turgor regardless of whether the vase contains sufficient water. Studies on different *Anthurium* cultivars have revealed that the difference in vase life can be explained primarily by differences in water uptake, water loss and tissue water status (Winston & Pathmanathan, 2024) [33]. Hydration treatments are therefore fundamental, especially for *Heliconia* for which cultivar-specific responses to preconditioning and vase hydration have been described (Linares-Gabriel *et al*., 2019) [17].

In practice this means that vase-life protocols should begin with clean cutting tools, rapid rehydration, the appropriate harvest stage and a solution that supports uptake without excessive osmotic stress. Hydration is not independent of temperature; high temperature increases transpiration and respiration, while very low temperature may cause chilling injury in chilling-sensitive tropical species (Aghdam *et al*., 2016; Buanong & Uthairatanakij, 2020) [1, 5].

2.2. Carbohydrates, Respiration, and Membrane Stability

Detached flowers, cut off from their photosynthetic supply, depend on their stored reserves or exogenous carbohydrates. Sugars can be used in respiration, for osmotic adjustment, to open and maintain petal structures and to maintain cell structures, but high concentration may reduce water uptake or encourage microbial growth. Studies on orchid production and postharvest handling emphasise the significance of sugar status for flower quality. Research on Mokara orchid associates growth regulation and sugar-related responses to cut-flower performance (Khandaker *et al*., 2017; De & Singh, 2016) [9, 16]. Current practice therefore favours balanced formulations instead of sugar alone. Carbohydrate source is most effective in combination with acidification and microbial control and the optimal concentration is dependent on species and cultivar. The use of simple, readily available solutions remains relevant when it is targeted at preserving biochemical status along with appearance, as demonstrated by recent work on low-cost preservatives in *Spathoglottis plicata* (Saikia *et al*., 2026) [28].

2.3. Microbial Blockage and Oxidative Stress

Microorganisms in vase water can colonize the cut stem, produce extracellular material, and restrict water movement. Microbial contamination also accelerates tissue deterioration and can interact with oxidative stress. This explains the persistent importance of antimicrobial components, although concerns about phytotoxicity, environmental persistence, and worker safety have encouraged investigation of alternatives to conventional biocides (Costa *et al*., 2021; Rashed *et al*., 2024) [8, 26].

Reactive oxygen species increase during wounding, dehydration, chilling, and senescence. Antioxidant systems involving ascorbate, phenolic compounds, enzymatic defenses, and stress-signaling molecules can delay membrane deterioration. In *Anthurium*, salicylic acid and ascorbic acid treatments have been investigated specifically in relation to chilling injury, antioxidant metabolism, and endogenous signaling (Aghdam *et al*., 2016; Mohammadi *et al*., 2023) [1, 20]. These studies support a broader trend: successful preservatives increasingly target both microbial contamination and internal stress physiology.

3. Recent Trends in Chemical and Biological Preservatives

3.1. Integrated Holding Solutions

Holding solutions are the most accessible intervention at the disposal of growers, wholesalers, retailers and consumers. More recent studies with *Heliconia* have assessed combinations of carbohydrates, acidifiers, antimicrobial agents and growth regulators to maintain water uptake and reduce stem deterioration (Carrera-Alvarado & Baltazar-Bernal, 2022; Carrera-Alvarado *et al*., 2021) [6, 7]. Treatment efficacy appears to be dependent on cultivar, harvest maturity, solution concentration and whether the treatment is applied as a pulse, a holding solution or both, suggesting these factors are important.

Historically, silver thiosulphate and other ethylene management strategies have been used in ornamentals, but environmental and regulatory restrictions on these materials have driven research into safer alternatives. The influence of aloe vera and silver thiosulphate treatments on microbial populations and vase life has been evaluated in *Heliconia*, indicating the shift from a single active compound to hybrid formulations (Shokalu *et al*., 2021) [29]. Future formulations should include days of vase life, water uptake, solution pH, microbial counts, visual quality scores and phytotoxicity.

3.2. Salicylic Acid, Ascorbic Acid, and Signaling Compounds

Salicylic acid is being looked at as a stress-modulating treatment, not only as a preservative. It has been applied to reduce chilling injury in *Anthurium*, and in *Heliconia*, it has been evaluated in combination with waxing and cold storage (Aghdam *et al*., 2016; Alvarado *et al*., 2019) [1, 3]. Salicylic acid is likely to be useful because it can affect antioxidant defences, membrane stability and stress signalling, but responses are very dose dependent.

Ascorbic acid provides a complementary strategy in that it can act as an antioxidant and potentially interfere with salicylic-acid biosynthesis. Research on *Anthurium* during cold storage reported reduced chilling injury in association with ascorbic acid treatment and enhanced salicylic acid biosynthesis (Mohammadi *et al*., 2023) [20]. These results are encouraging for tropical flowers, but commercial protocols need to be tested under fluctuating temperatures and not just in controlled storage in the laboratory.

3.3. Essential Oils and Plant Extracts

One of the most obvious eco-friendly trends in vase-life research is the utilisation of essential oils and botanical

extracts. They may offer antimicrobial activity, antioxidant properties, biodegradability, and compatibility with consumer demand for reduced synthetic inputs. For example, peppermint essential oil has recently been evaluated to extend the vase life of Dendrobium orchids (Teerarak *et al*., 2024) [30]. *Aloe vera* has also been studied in *Heliconia*, where it was associated with microbial and vase-life results (Shokalu *et al*., 2021) [29].

However, the composition of botanical products is chemically variable. Their effectiveness can be affected by plant origin, extraction method, chemotype, concentration, emulsifier and application route. At high concentrations, essential oils can also cause tissue injury or undesirable odour. Reviews of essential oils and herbal extracts highlight their promise but also the need for standardised formulations and comparative testing (Banjaw, 2017; Kantharaj *et al*., 2018) [4, 14]. Recent data from non-tropical flowers, such as gladiolus treated with Calotropis leaf extract, further support the hypothesis that plant extracts can improve water relations, antioxidant defence, and microbial control, but transfer to tropical species must be demonstrated rather than assumed (Akhtar *et al*., 2026) [2].

3.4. Melatonin and Other Emerging Biostimulants

Melatonin is a candidate eco-friendly preservative, due to its ability to regulate antioxidant metabolism, delay ageing, and improve stress tolerance. A recent review reported that melatonin is a promising treatment in cut flowers, but trials specific to tropical flowers are limited (Nguyen & Ha, 2025) [22]. The same absence of evidence is true for many biostimulants. Seaweed extracts, humic substances, amino-acid products and microbial preparations are well established in crop production but their use in postharvest of tropical cut flowers requires more targeted validation.

Studies on anthurium and orchids show a growing interest in biostimulants for plant vigour, flower quality and production performance (Hegde *et al*., 2020; Thomas *et al*., 2024) [12, 32]. The next step is to link preharvest biostimulation to postharvest outcomes. Treatments that increase stem diameter or carbohydrate reserves may indirectly prolong vase life, but this should be evaluated through coordinated pre-harvest and post-harvest experiments.

4. Physical Treatments, Packaging, and Storage

4.1. Waxing and Surface Protection

Waxing acts as a barrier to water loss and may be particularly beneficial to large-bracted inflorescences. Waxing has also been studied in *Heliconia wagneriana* in conjunction with cold storage and salicylic acid, which is in line with the current trend of combining treatments instead of isolated interventions (Alvarado *et al*., 2019) [3]. But surface coatings must balance reduction of transpiration with gas exchange and appearance. Too impervious coatings may create anaerobic conditions, change colour or result in an unnatural sheen.

4.2. Cold Storage and Chilling Injury

Cold storage retards respiration and microbial development, but is not universally beneficial to tropical species. Anthurium and other tropical flowers suffer chilling injury at temperatures that temperate flowers can tolerate. Symptoms are discolouration, loss of gloss, poor opening, tissue collapse and accelerated deterioration after transfer to room temperature (Aghdam *et al*., 2016; Mohammadi *et al*., 2023) [1, 20]. This makes temperature optimisation species-specific and emphasises the need to distinguish between storage life and subsequent vase life.

The modified and controlled atmosphere conditions have been studied to control biochemical changes and senescence in stored orchids (Poonsri, 2020, 2021) [24, 25]. These approaches can reduce metabolic activity, but the package atmosphere has to be tailored to the flower respiration and permeability. Too tight an atmosphere can lead to fermentation and off-odors.

4.3. Modified-Atmosphere Packaging and Sustainable Materials

Packaging research is moving away from simple protection against mechanical damage to active control of humidity, oxygen, carbon dioxide and microbial conditions. Dendrobium orchids have been evaluated for passive and active modified atmosphere packaging with effects on biochemical properties and postharvest quality (Poonsri, 2021) [25]. In more extensive reviews on packaging, it is noted that the selection of materials affects condensation, gas exchange, temperature stability and the preservation of visual quality (Franzoni *et al*., 2024; Rashed *et al*., 2024) [11, 26].

Tropical flowers also require packaging that can survive long supply chains and intermittent refrigeration. Biodegradable films, antimicrobial coatings, and controlled-permeability materials are attractive, but their environmental performance needs to be assessed over the complete life cycle. Packaging should not be judged solely on the basis of days of added vase life. Considerations of material use, disposal, recycling, and food-contact or worker-safety also are important.

5. Nanotechnology and Digital Quality Assessment

Nanotechnology is one of the fastest developing trends in postharvest floriculture. Silver nanoparticles are antimicrobial, and silicon-containing materials can increase stress tolerance and tissue strength. The effects of silver and silicon nanoparticles on microbial populations and physiological quality in cut flowers have been documented, and the effects of biologically synthesised silver nanoparticles in gladiolus using Piper betle have been studied (Kamiab *et al*., 2017; Maity *et al*., 2019) [13, 18]. In *Strelitzia reginae*, graphene oxide with silver nanoparticles was explored as a biostimulant for postharvest life, demonstrating the trend toward multifunctional nanocomposites (Thakur *et al*., 2022) [31].

Nanoparticles are a promise that needs to be evaluated with unusual care. Efficacy is dependent on particle size, surface chemistry, concentration, aggregation, and route of exposure. Silver and copper can enter wastewater. Plant uptake or residue behaviour is not sufficiently understood for many ornamental systems. In floriculture, nanotechnology reviews have suggested standardised reporting, environmental risk assessments, and comparison with lower-risk alternatives (Keerthana *et al*., 2024; Sahu, 2023) [15, 27]. Nanotechnology should therefore be considered as a promising but not yet commercially ubiquitous technology.

Another rising trend is digital phenotyping. Image-based assessment enables a more objective quantification of colour, area, curvature, opening and structural deterioration than

visual scoring alone. Computer-assisted assessment has also been shown to be relevant to tropical ornamentals, as demonstrated by an image-based approach applied to postharvest characterisation of Red Torch inflorescences (Nogueira *et al*., 2024) [23]. A combination of images with temperature, humidity, solution uptake and gas data could lead to early prediction of loss of marketability.

6. Comparative Assessment and Research Limitations

The strongest tropical-specific evidence currently concerns water relations, chilling injury, microbial control, and species-specific preservative responses. Anthurium research emphasizes hydration and chilling physiology; Heliconia research emphasizes hydration, waxing, salicylic acid, antimicrobial solutions, and cultivar variation; and orchid research increasingly emphasizes carbohydrate management, essential oils, modified atmospheres, and storage biochemistry (Linares-Gabriel *et al*., 2019; Malakar *et al*., 2023; Poonsri, 2020, 2021; Winston & Pathmanathan, 2024) [17, 19, 24, 25, 33].

Several limitations constrain comparison across studies. First, vase life is defined inconsistently: some studies use visible senescence, others use a fixed quality score, petal or bract discoloration, or marketability thresholds. Second, treatment concentrations and exposure times vary widely. Third, many experiments use small sample sizes, a single cultivar, distilled water, and stable laboratory temperatures. Fourth, tropical flowers are often discussed together even though their tissues, inflorescence architecture, chilling sensitivity, and ethylene responses differ. Finally, positive results are not always accompanied by economic analysis, microbial enumeration, residue data, or supply-chain validation.

Meta-analysis and machine-learning approaches are beginning to address these limitations by comparing preservation efficacy across treatments and identifying interacting factors (Neto *et al*., 2023; Wu *et al*., 2025) [21, 34]. Their value will depend on better primary-study reporting. Future publications should provide cultivar identity, harvest maturity, stem dimensions, preharvest conditions, treatment pH, temperature and relative humidity, solution renewal, sample size, statistical model, and a clear definition of commercial vase life.

7. Future Directions

Recent literature identifies five priorities. First, design protocols as systems. A practical treatment may be a combination of pulsing, hydration, antimicrobial control, antioxidant protection and optimised packaging rather than a single active ingredient. Second, cultivars require specific protocols because water relations and chilling tolerance can vary significantly even within a single species (Dung *et al*., 2016; Winston & Pathmanathan, 2024) [10, 33].

Third, sustainability should be considered from the beginning. Natural extracts, biodegradable packaging and reduced-silver formulations are promising, but they need to be quantitatively compared in terms of production, stability, waste streams and efficacy . Fourth, decision making must be linked to digital instruments. Image analysis and low-cost sensors can support dynamic shipment routing, retail replacement choices, and consumer advice (Nogueira *et al*., 2024) [23]. Fifth, research must link preharvest quality with postharvest longevity. The biochemical reserve with which a stem enters the supply chain can be dictated by biostimulants, nutrition, canopy microclimate and harvest timing.

A high priority experimental design would be to compare conventional preservative solution, natural-product treatment, nanoparticle treatment and combined low-dose program in several tropical species. Results should include vase life, water uptake, microbial load, oxidative markers, chilling injury, appearance, environmental footprint and cost per marketable stem. Such designs would yield more useful evidence than isolated demonstrations of a single treatment.

8. Conclusion

Recent vase-life research in tropical cut flowers is moving from conventional preservation toward multi-target and more sustainable postharvest systems. The most consistent opportunities involve improving water relations, controlling microbial blockage, moderating oxidative stress, and avoiding chilling injury. Salicylic acid, ascorbate, essential oils, plant extracts, biostimulants, modified atmospheres, coatings, nanoparticles, and image-based monitoring each contribute useful tools, but none is universally effective across tropical species. The evidence is strongest when treatments are matched to species physiology and evaluated under realistic handling conditions. Commercial progress will depend on standardized protocols, transparent reporting, environmental assessment, and integration of biological, chemical, physical, and digital technologies.

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