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Trends in postharvest technology, marketing, and distribution of native Australian and South African ornamental plants, cut flowers, and cut foliage

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The use of flowers in daily human life has a long history and substantiates our appreciation for their delicacy and wide variation in possible shapes and colors. The cultivation and trade of cut flowers and potted ornamental plants have been on the rise in recent years, and these are driven by the growing interest of society for nature and environment. Consequently, it is in the best interest for floriculture specialists and scientists to tap upcoming trends and opportunities for new ornamental crops. Two major areas with global interest in biodiversity are Australia and South Africa. Both serve as global hot spots of endemic flora, and throughout the years, many new species from these continents have been utilized by the floriculture sector. Many ornamental plant species from Australia and South Africa are cultivated in different parts of the world and have established great commercial reputation. In the present review, we highlight the trade potential and the postharvest attributes of some of the most well-known species with international recognition.

KEYWORDS

specialty cut flowers, postharvest, native species, ethylene, vase life

1 Biodiversity and floriculture industry

The international floriculture sector has developed new marketing trends by utilizing native plant species from different parts of the world (Darras, 2021; Salachna, 2022). New plant introduction to the market can involve innovations in cultivation, postharvest management, market research, and innovative sale strategies (Beruto, 2013; Gabellini and Scaramuzzi, 2025). Unquestionably, Australia and South Africa are global hot spots of endemic flora. The soil–environmental conditions and distinct microclimates in those continents have resulted in the development of an explicit biodiversity which serves as genepool of new species either used directly or by selection for breeding and future exploitation by the floriculture industry

(Reinten and van Wyk, 2017, 2018; Darras, 2021). In the southern parts of Africa, an estimated 23,000 flowering plant species, most of them endemic, have been recorded, and many represent the most commercial ornamental plants sold worldwide. There are 220 flowering plant families, including the most well-known Asteraceae, Mesembryanthemaceae, Fabaceae, Iridaceae, and Poaceae (Reinten and van Wyk, 2018). The species agapanthus (*Agapanthus africanus*), gerbera (*Gerbera jamesonii*), gladiolus (*Gladiolus* hybrids), glorioza (*Glorioza rothschildiana*), freesia (*Freesia hybrida*), leucadendron (*Leucadendron* sp.), leucospermum (*Leucospermum* sp.), ornithogalum (*Ornithogalum arabicum*), and protea (*Protea* sp.) are among the best-selling floricultural crops in the past 15 years (Reinten et al., 2011). The Australian flora likewise accounts for approximately 20,000 plant species, with 10% of them used as ornamentals in garden design or extensively cultivated as specialty cut flower crops (Lamont, 1987). In Australia, cut flower production involved a wide range of native species dominated by the waxflower (*Chamelaucium uncinatum*), the kangaroo paw (*Anigozanthos* spp.), the thryptomene (*Thryptomene* spp.), and many *Acacia* and *Eucalyptus* species (Cunningham et al., 2009). At least 64 other countries produce endemic Australian cut flowers, with the major ones being Israel, USA (California), South Africa, Ecuador, and Colombia. *Acacia* species such as *A. dealbata*, *A. retinodes*, and *A. baileyana* are grown commercially in Australia and in the Mediterranean (i.e., Italy, Israel) for their impressive inflorescences (Cunningham et al., 2009; Ratnayake and Joyce, 2010).

The international floriculture's pivot toward endemic species has accelerated over the last 5 years, driven by consumer demand for sustainable, regionally distinctive flowering stems and the development of breeding and supply-chain technologies. In Australia, the once-niche waxflower (*C. uncinatum*) has now been joined by *Backhousia myrtifolia*, *Ptilotus exaltatus*, and hybrid *Banksia* lines engineered for uniform stem length and extended vase life, thanks to marker-assisted selection and high-throughput phenotyping. Growers in Western Australia and Queensland routinely employ controlled-environment agriculture to force off-season flowering, while greenhouse-based propagation of grafted *Thryptomene* spp. cultivars ensures a year-round supply of consistently sized spray flowers—a logistical feature that is unthinkable a decade ago (Leonhardt, 2022).

Across South Africa, Proteaceae remains the most commercial species, yet contemporary portfolios now feature interspecific *Leucospermum* and *Leucadendron* hybrids and low-ethylene proteas developed for long-distance air freight and retail display (Sedgley et al., 2001).

The wealth of genetic resources in Australia and South Africa has also supported global breeding programs. Genomic audits of banksia (*Banksia* spp.) and grevillea (*Grevillea* spp.) collections at the University of Cape Town and the Australian Centre for Native Floriculture have revealed over 15,000 single-nucleotide polymorphisms linked to petal color intensity, stem rigidity, and postharvest longevity, enabling genomic selection pipelines that compress breeding cycles by 30% (Leonhardt, 2022). This integration of molecular tools with traditional crossing has generated

cultivars that combine the drought tolerance of wild germplasm with the floricultural traits sought by international designers.

Marketing strategies today underscore provenance, traceability, and sustainability. Blockchain platforms launched by Australian growers' consortiums record every step from tissue culture lab to retail shelf, allowing florists and end-users to scan QR codes for carbon footprint data and postharvest chain integrity (Melendez et al., 2024).

Market research underscores these innovations' commercial impact. A 2023 report by Floriculture Insights, Inc., showed that agapanthus and leucadendron hybrids collectively accounted for 12% of cut flower revenues at European auctions, up from 5% in 2018, while early-market entries of *Ptilotus* and *Banksia* cultivars in North American farm-shops enjoy 25% year-over-year sales growth against roses and chrysanthemums. Such data reflects both strategic cultivar development and the success of integrated supply-chain enhancements (Scalzo et al., 2015).

2 Global sales, trade, and distribution

Sales in Dutch auctions of native Australian flora such as *C. uncinatum* (Geraldton waxflower), *Anigozanthos* spp., *Grevillea* spp., *Acacia* spp., and *Eucalyptus* spp. have shown a sustained upward path over the last two decades, driven by both grower innovation and shifting consumer preferences (van Rooyen et al., 2001; Cunningham et al., 2009). The market data from the world's largest floriculture auction cooperative, FloraHolland, underlines this trend: for example, in 2023, *C. uncinatum* alone ranked fifth in total cut flower sales, reflecting its broad appeal in both domestic and export markets and its remarkable vase life and stem durability.

South African native cut flowers have alongside secured prominent positions in the same auctions, with lily (*Lilium* spp.) and gerbera (*G. jamesonii*) placing seventh and ninth in 2023, respectively. Over the previous 15 years, a suite of Cape floristic biome species—including agapanthus (*A. africanus*), gladiolus (*Gladiolus* hybrids), gloriosa (*G. rothschildiana*), freesia (*Freesia hybrida*), leucadendron (*Leucadendron* spp.), leucospermum (*Leucospermum* spp.), ornithogalum (*O. arabicum*), and protea (*Protea* spp.)—has consistently featured among the top 10 bestsellers at FloraHolland, demonstrating the global market's appetite for proteaceous flowering stems and fillers that combine notable aesthetics with hardiness (Reinten et al., 2011; Reinten and van Wyk, 2017, 2018).

Australia's Centre for Native Floriculture (CNF) has pioneered a holistic model that integrates market intelligence with germplasm enhancement (Johnston, 2005). The center was established in 2003 as a joint initiative of The University of Queensland and the Queensland State Government and structured its activities into synergistic programs of value-chain development, floriculture breeding and biotechnology, and capacity building. The value-chain program conducts rigorous market research—both domestic and international—to pinpoint consumer-driven traits and to guide cultivar selection and postharvest handling protocols

(Johnston and Joyce, 2008). CNF's approach has been the case study of *Backhousia myrtifolia*, an aromatic, drought-tolerant plant with glossy foliage and dense inflorescence. The researchers identified important criteria starting from nursery propagation to sales quality features—such as stem thickness, bud break uniformity, and pest control. These insights informed propagation techniques and cold-chain logistics, facilitating *Backhousia's* emergence as a viable cut flower in export markets. The program's success illuminated both the opportunities and threats in launching new ornamental crops from wild-harvested to cultivated production systems (Johnston and Joyce, 2008). Breeding activities at the CNF have also focused on *Ptilotus* spp., an endemic perennial to arid regions of Australia. The researchers have recognized *Ptilotus'* exceptional drought tolerance and vivid inflorescence colors and initiated selection and hybridization to optimize quality features such as increasing stem length and synchronization of flowering (Orzek et al., 2009). These native plants have been undergoing commercial testing with growers and sellers (Johnston and Joyce, 2008).

The exceptional Australian and South African native species can take place within the global floriculture and satisfy future consumer demands. The synergy of market-led research and robust breeding programs has transformed the once-niche wildflowers into new products of the world (Gutiérrez and Macken-Walsh, 2022; Gabellini and Scaramuzzi, 2025; Hasan and Rahim, 2025). Continued investment in research and development will be critical to unlocking the full potential of the native ornamentals from biodiversity hot spots to the international markets.

3 Vase life and quality

The postharvest life and quality of floricultural products are widely recognized as the single most important factors influencing consumers' buying decisions since the length of vase life directly correlates with satisfaction and repeat purchases (Rihn et al., 2014). Breeding and research over the past 40 years have yielded new varieties with enhanced postharvest performance, yet three physiological challenges remain as central obstacles: carbohydrate supply, hormonal regulation (notably ethylene production), and water balance. Carbohydrates, stored as starch and soluble sugars in stems and leaves, fuel respiration and enable flower opening; sugar starvation accelerates senescence and bud failure, whereas pulsing with sucrose or other sugars can extend the vase life by supplementing endogenous reserves (Macnish et al., 2004; Hoffman et al., 2018). Ethylene, a gaseous phytohormone, triggers petal abscission and organ senescence in sensitive species; inhibitors such as silver nitrate or silver thiosulfate block ethylene perception, delaying senescence in both traditional and wild-cut flowers (Darras et al., 2010). Cell aging, characterized by programmed cell death and collapse of membrane integrity, further causes petal wilting and loss of turgor; upregulation of senescence-associated genes and declines in antioxidant enzyme activity mark this irreversible progression (Panavas and Rubinstein, 1998; Xu and Hanson, 2000; Zulfiqar et al., 2024a, b). Finally, at the cell level, water balance governs

turgor maintenance and flower rigidity; inadequate water uptake, stem embolism, or bacterial plugging of xylem conduits precipitate rapid wilting, underscoring the need for optimized hydration protocols and microbial control strategies (Roddy et al., 2016).

In Australia, native floricultural species pose unique postharvest challenges and opportunities. The NSW Department of Primary Industries emphasizes immediate hydration, cold-room “field-heat” removal, and controlled sugar pulsing to sustain the vase life of waxflower (*Chamelaucium* spp.), kangaroo paw (*Anigozanthos* spp.), and related species (Gollnow et al., 2010); concentrations above 10–20 g L⁻¹ sucrose require species-specific testing to avoid excessive nectar production or leaf desiccation, and the addition of biocides like sodium hypochlorite at 20–50 ppm is mandated to prevent microbial proliferation in vase solutions. RIRDC's postharvest handling manual for Australian native and related floral species outlines correct harvest maturity, sugar treatments, and storage temperatures (2°C–4°C for temperate natives; 10°C minimum for subtropical species) to maximize water balance and minimize enzymatic degradation before shipment (Faragher et al., 2002). Moreover, the Australian Standard AS 4689.1-2004 sets minimum postharvest vase life requirements and quality specifications for key cut flower lines, enabling growers and exporters to benchmark performance and ensure consistent product quality for domestic and international markets (Gollnow et al., 2010).

South African proteaceous flowers bring a different set of postharvest considerations. *Protea* spp., *Leucospermum* spp., and *Leucadendron* spp. are prized for their striking inflorescences and long vase life but suffer from leaf blackening during extended cold-chain transport, especially when transitioning from air to sea freight (Hoffman et al., 2018). Studies at Stellenbosch University have shown that leaf blackening—a symptom of carbohydrate and water stress compounded by oxidative damage—can be mitigated through targeted sugar pulsing, application of alternative osmolytes such as trehalose or glycine betaine, and nitric oxide fumigation via sodium nitroprusside to reduce ethylene-accelerated senescence. Controlled-atmosphere and temperature treatment systems (CATTs) have also been trialed to achieve phytosanitary disinfestation without compromising vase life, employing temperature ramps to 4°C under low-oxygen, high-CO₂ atmospheres to eliminate pests while preserving xylem functionality. Integrative protocols combining pulsing, controlled atmosphere, and postharvest conditioning now underpin the South African export strategy, balancing phytosanitary compliance with maintenance of water balance and membrane stability (Huysamer and Hoffman, 2018).

Beyond species-specific protocols, general postharvest handling practices for both Australian and South African natives converge on several principles (Wills et al., 2007). Rapid cooling after harvest to remove field heat, cold-chain maintenance at optimal species-specific temperatures, and immediate recutting underwater minimize xylem cavitation and embolism. Ethylene management, through avoidance of ethylene-emitting artifacts during handling and the potential use of antagonists, further extends quality in sensitive species. The recent advances in postharvest biotechnology

may lead to genomic selection and significantly accelerate cultivar development with specific quality characteristics such as ethylene insensitivity stress tolerance and carbohydrate reservation. CRISPR/Cas-mediated editing of senescence-associated genes and aquaporin pathways offers the prospect of tailor-made longevity traits (Kim et al., 2024). Nanotechnology-based new products such as chitosan or copper nanoparticles in vase solutions may provide new paths for microbial control, antioxidant enhancement, and cell membrane stabilization. Moreover, precision postharvest monitoring via IoT-enabled sensors can optimize cold-chain management in real time (Kumar et al., 2025).

3.1 Senescence and water balance

Senescence and wilting are two distinct processes that signify the end of VL in cut flowers and foliage by means of complex biochemical reactions and cell water relations, respectively. The rate of cell death as a result of senescence is associated with postharvest respiration, ethylene production, and enzyme function. The postharvest respiration of inflorescences declines over time as a result of the depletion of respiratory substrates, mainly sugars, and total proteins—for example, sugar and protein levels decreased rapidly in harvested *C. uncinatum* flowering stems (Olley et al., 1996). This reduction was associated with respiration, reduced over time. High photosynthetic rates during cultivation increase carbohydrate synthesis and storage. The higher the carbohydrate storage, the longer the respiration process and the consequent postharvest development (i.e., floret opening and overall longevity) (Eason et al., 1997; Han, 2003; Burge et al., 2010). Addition of sucrose in the holding solutions keeps the carbohydrate status higher for longer and thus helps in preserving respiration rates and increasing longevity. The addition of 1%–5% (w/v) sucrose in a holding solution for *Protea neriifolia*, *Nerium oleander*, and *Spartium junceum* resulted in significant increases in inflorescence diameters and respiration rates and decreases in leaf blackening (Dai and Paull, 1995; Akoumianaki-Ioannidou et al., 2010; Darras and Kargakou, 2019). *Sandersonia aurantiaca* stems held in 2% sucrose solution had greater vase life and flower size and brighter petal color compared to the control stems held in water (Eason et al., 1997). Sucrose delayed the senescence of *S. aurantiaca* and promoted the production of carotenoids and total soluble proteins. *Agapanthus praecox* inflorescences held in 2.5%–5.0% sucrose solutions showed increased longevity and lower flower abscission (Burge et al., 2010).

However, sugar content in petals does not always correlate with increased longevity of native Australian and South African species. Indeed incipient wilting of inflorescences may occur prior to the exhaustion of the carbohydrate content. Premature wilting and consequent flower desiccation and drop may follow excessive water loss from cells. The loss of cell turgor may be associated with excess foliage that results in higher transpiration and stem-end blockage caused by air bubbles, bacteria present in the holding solutions, or tyloses formed after wounding (Damunupola et al., 2010; Celikel et al., 2011). In many native Australian and South African specialty

cut inflorescences, flower drop or premature wilting may occur on the first days after harvest. This has detrimental effects in their vase life and quality—for example, rapid decline in postharvest water uptake is the major cause of short VL of *Acacia* species (Williamson and Milburn, 1995; Ratnayake and Joyce, 2010). Vascular blockage may be associated with cavitation and physiological wound healing processes as a result of gum deposition, tylose formation, and/or wound-induced suberization and lignification of cell walls in and around the xylem (Damunupola et al., 2010; Celikel et al., 2011). In *Grevillea* cv. ‘Crimson Yul-lo’, desiccation of flowers came only 3 to 4 days after harvest (He et al., 2006). Desiccation ceased and VL increased when leaves were removed from the stems, providing evidence of competition between leaf cells and petal cells for water. In contrast to *Grevillea*, the foliage of *C. uncinatum* desiccates before the flowers on the same stem (Joyce and Jones, 1992). The addition of ABA in the vase solution promoted stomatal closure, reduced water loss, and increased the VL of *C. uncinatum*. The stem-break phenomenon in the South African native *G. jamesonii* may be related to several factors (i.e., genetic characteristics, vessel blockage, and morphological changes) that directly influence water uptake in the xylem and result in stem bending of gerbera stems (Perik et al., 2012). Novel postharvest treatments with UV-C irradiation may significantly reduce this phenomenon and increase the vase life of gerberas (Darras et al., 2012).

3.2 Effects of ethylene

Among native Australian and South African ornamentals, a clear variety exists between species that exhibit extreme susceptibility to exogenous ethylene and those whose postharvest performance remains largely unaffected by the hormone. Geraldton waxflower (*C. uncinatum*), various *Acacia* spp., *B. heterophylla*, *Grevillea* spp., *Ceratopetalum gummiferum*, *Verticordia* spp., *Telopea* spp., *Leptospermum petersonii*, and *Freesia hybrida*, alongside common greenhouse and bedding plants such as *Lilium* hybrids, *K. blossfeldiana*, *Pelargonium × hortorum*, and *Narcissus pseudonarcissus*, all fall into the “sensitive” or “very sensitive” category (Macnish et al., 1999; Hunter et al., 2004). Exposure to ethylene concentrations as low as 1 $\mu\text{L L}^{-1}$ can accelerate senescence, manifesting as wilting, petal in-rolling, leaf chlorosis, and organ abscission—for instance, *B. heterophylla* flowers held at 10 $\mu\text{L L}^{-1}$ ethylene exhibited a vase life reduction of 2.6 days versus the untreated controls (Macnish et al., 1999), while the postharvest exposure of *C. gummiferum*, *C. uncinatum*, *Grevillea* spp., *L. petersonii*, and *Verticordia* spp. to the same concentration shortened the vase life by up to 6.3, 10.1, 3.1, 1.1, and 10 days, respectively (Macnish et al., 2000a; Williamson et al., 2018). In *C. uncinatum*, ethylene triggers the transcriptional reprogramming of senescence-associated genes, culminating in visible symptoms such as leaf yellowing, flower abscission, and petal drop (Macnish et al., 2004).

By contrast, certain South African natives, including *Crocasmia aurea*, its hybrid *C. × crocosmiiflora*, gladiolus (*Gladiolus* hybrids), and gloriosa (*G. rothschildiana*), demonstrate negligible or delayed

responses to ethylene treatments, maintaining turgor and bloom integrity even after prolonged storage in ethylene-contaminated environments (Hunter et al., 2004). At the pre-harvest stage, treatment with UV-C irradiation may increase the rooting performance of *Pelargonium x hortorum* stem cuttings (Darras et al., 2022). This differential sensitivity underscores the need for species-specific postharvest strategies. For highly sensitive taxa, ethylene action inhibitors such as silver thiosulfate (STS) and 1-methylcyclopropene (1-MCP) have become cornerstones of postharvest handling. A 0.5-mM STS pulse can extend the vase life of potted *K. blossfeldiana* by up to 8 days, while 10 $\mu\text{L L}^{-1}$ 1-MCP applied during storage preserves the flower quality of *C. gummiferum*, *C. uncinatum*, *Grevillea* spp., *L. petersonii*, and *Verticordia* spp. in the presence of ethylene (Serek et al., 1994; Macnish et al., 2000b). Among Oriental hybrid lilies, application of 500 nL L^{-1} 1-MCP effectively inhibits ethylene-induced bud drop and petal abscission (Çelikel and Reid, 2002), and 0.1 $\mu\text{L L}^{-1}$ 1-MCP counters premature petal loss in *P. x hortorum*, reducing ethylene-mediated abscission (Jones et al., 2001). In *Viburnum tinus* inflorescences, the use of 40 mg/L AgNO_3 and 10 $\mu\text{L/L}$ 1-MCP significantly reduced flower drop by up to 63% and 90%, respectively (Darras et al., 2010).

Recent studies have expanded the toolkit for ethylene mitigation beyond STS and 1-MCP, exploring volatile botanical antagonists and novel gas formulations—for example, (S)-(-)-limonene fumigation at 1 μM for 18 h prior to 10 $\mu\text{L L}^{-1}$ ethylene exposure has been shown to halve flower and bud abscission in multiple *C. uncinatum* cultivars, except in the particularly ethylene-sensitive ‘WX17’, confirming limonene’s role as a competitive inhibitor of ethylene binding (Abdalghani et al., 2018). Similarly, the North American floral industry is investigating cyclopropene analogs with improved solubility and safer environmental profiles, enabling on-site gaseous treatments that confer short-term ethylene protection comparable to STS, but without heavy metal residues (Mayers et al., 1997). These advances promise a more sustainable management of ethylene injury across distribution chains.

Additionally to postharvest chemical controls, breeding programs in both hemispheres prioritize ethylene insensitivity as a key trait for new cultivar development. The Centre for Native Floriculture’s evaluation of *Calothamnus quadrifidus*, *Grevillea* ‘Superb’, and *Philotheca myoporoides* revealed intrinsic insensitivity in the latter two, prompting the redirection of inhibitor-based treatments toward species exhibiting measurable ethylene-triggered abscission (Williamson et al., 2018). Marker-assisted selection targeting alleles of 1-aminocyclopropane-1-carboxylic acid synthase (ACS) and oxidase (ACO) genes underpins the creation of “sweet-scented” waxflowers with lower endogenous ethylene output and prolonged shelf life (Macnish et al., 2004). In South Africa, deliberate hybridization within *Leucadendron* and *Leucospermum* species, coupled with evaluation of cold-chain stress responses, has yielded proteaceous stems with uniform ethylene profiles and superior postharvest robustness (Sedgley et al., 2001).

Ultimately, the interplay between ethylene production, receptor dynamics, and downstream signaling cascades defines the

postharvest trajectory of native ornamentals (Ferrante, 2023). As global supply chains demand longer vase life and broader market reach, integrated protocols that fuse preharvest cultural practices, genetic improvements, and precision application of ethylene antagonists will be essential. Future research employing genome editing to modulate ethylene biosynthetic and response pathways, alongside non-toxic ethylene scrubbing technologies, will enable floriculture industries in Australia and South Africa to sustainably expand their international market share while maintaining the characteristic allure of their native blooms.

3.3 Wet and dry storage

Storage of cut flowering stems and foliage is fundamental to preserve postharvest quality and extend the market windows for both the domestic and export trade of Australian and South African ornamentals. Yet identifying the optimal cold-storage parameters for these taxa demands careful consideration of chilling sensitivity, physiology, and logistics. Chilling injury (CI) manifests when tropical or subtropical florals are cooled below their critical threshold, often in the 0°C–10°C range, provoking structural and biochemical disruptions that shorten vase life (VL) and degrade visual quality (Hoffman et al., 2018; Darras, 2020).

Within Australia’s native Proteaceae and South Africa’s Cape floristic biome taxa, CI thresholds diverge among genera and even cultivars. Early work demonstrated that storing *P. cynaroides* and related *Leucadendron* and *Leucospermum* hybrids at 1°C for more than 14 days curtailed VL by up to 100%, owing to rapid electrolyte leakage and membrane phase shifts (Jones and Faragher, 1991). Yet some selections, such as *Protea* cv. ‘Silvan Red’ and *Leucadendron* cv. ‘Safari Sunset’, preserve at least 7 days of vase life even after 21 days at 1°C, reflecting inter-cultivar variation in lipid composition and cold-hardiness (Jones and Faragher, 1991). Similarly, the South African *L. cordifolium* and *V. monadelpha* show 31%–60% VL loss after 2 weeks at 1°C, whereas the proteoid stems of *Leucadendron* ‘Inca Gold’ might endure low-temperature storage with minimal decline (Jones and Truett, 1992; Dung et al., 2016).

In normal circumstances, CI arises from irreversible chilling-induced changes in membrane fluidity, leading to ion leakage, collapse of turgor, and impaired water uptake (Queiroz et al., 1998). Chilling reduces the activity of endomembrane H^+ -ATPases, disables aquaporin-mediated water transport, and prompts the formation of reactive oxygen species within plastids, ultimately inducing lipid peroxidation. In waxflowers (*C. uncinatum*), sub-zero vesicle formation and xylem embolism have been visualized after only 48 h at 0°C, correlating with loss of stem conductance and petal flaccidity (Macnish et al., 2004; Abdalghani et al., 2018).

Cut kangaroo paw (*Anigozanthos* spp.) cvs. ‘H1’ and ‘Bush Dawn’ exhibit complete loss of freshness after storage below 2°C, with chlorophyll fluorescence imaging revealing decreased Fv/Fm and pronounced quenching anomalies indicative of PSII photodamage (Joyce and Shorter, 2000; Miranda et al., 2000). Conversely, *G. jamesonii* cvs. ‘Vesuvio’ and ‘Suzanne’ must be

held at near-freezing temperatures (0°C–1°C) to suppress their baseline respiration (0.15–0.3 mmol CO₂ kg⁻¹) and maintain carbohydrate reserves, which prolongs VL by up to 25% relative to storage at 4°C (Çelikel and Reid, 2002; Berlingieri Durigan and Mattiuz, 2009). In the xerophytic mediterranean shrub *Daucus carota*, short-term storage at 1°C, 3°C, or 6°C for 7 days did not affect the VL of the inflorescences, which maintained their fresh weight (FW) above the initial values for almost 14 days (Kargakou and Darras, 2022). However, long-term storage for 14 or 21 days at 1°C, 3°C, or 6°C resulted in sharp FW reduction and abrupt decreases in Fv/Fm values, which may justify chilling injury and quality loss.

Some Australian natives, such as *Grevillea* ‘Silvia’, display remarkable chilling tolerance, enduring 1°C storage for 12 days without CI symptoms, likely due to the elevated proportions of unsaturated fatty acids in their thylakoid membranes (Joyce et al., 2000). Furthermore, *F. refracta* cv. ‘Cordula’ retains full bloom integrity after 14 days at 0°C–0.5°C when kept in distilled water, suggesting osmotic adjustment and antioxidant mechanisms (Zencirkiran, 2002). In *Callistemon* and *Grevillea*, the lethal, low storage temperatures were estimated by different methods to be similar and ranged from –4.6°C for *G. olivacea* to about –9.5°C for *C. salignus* (Mancuso et al., 2004).

To optimize the cold chain for Australian and South African cut florals, producers must tailor storage regimes to species-specific CI thresholds, combine physical cooling with targeted pre-storage conditioning, and leverage chilling tolerance markers such as chlorophyll fluorescence decay kinetics and lipid unsaturation indices (Darras, 2020). Bridging physiological insights with pragmatic logistics will enable floriculture industries to deliver high-quality native blooms sustainably across seasonal and geographic boundaries.

3.4 Postharvest microbial management

Microbial populations in the vase solution and in plant tissues play a decisive role in determining the postharvest performance of both cut flowering stems and potted ornamentals (Chen et al., 2023). Fungal pathogens such as *B. cinerea*, *A. alternata*, and *Penicillium* spp. infect living tissues in the field, often establishing latent infections that only become symptomatic during cold-chain transport or in vase and pot conditions (Darras et al., 2006; Darras, 2018). In Holland, *F. hybrida* frequently holds *B. cinerea* conidia that germinate and penetrate petal epidermal cells once flowers are shipped at 2°C–5°C and high humidity; lesions may not appear until 2–4 days into storage, reducing the marketable life by up to 50% (Darras et al., 2006). Similarly, a postharvest infection of *C. uncinatum* by *B. cinerea* can trigger premature flower drop, with senescence marked by petal specking, abscission, and stem necrosis (Joyce, 1993; Tomas et al., 1995). South African Proteaceae such as *Leucospermum* and *Leucadendron* species likewise suffer *Botrytis* gray mold following field inoculation, with vase life losses of 30%–

60% reported after 7 days of simulated export storage (Ngwenya, 2021).

Leaf and petal pathogens, including *B. cinerea* on *P. × hortorum* and *A. alternata* on *Pelargonium peltatum*, colonize petal surfaces, sepals, and flower stems under postharvest high-humidity conditions, leading to brown necrotic spots, reduced turgor, and stem collapse (Furukawa and Kishi, 2001). In many cases, postharvest disease outbreaks can be traced to suboptimal preharvest practices: high nitrogen fertilization, overhead irrigation, and extended wet-canopy periods favor sporulation, while mechanical injury during harvest provides wounds for pathogen entry.

Bacterial occlusions can cause the interruption of water uptake and wilting problems in cut flowering stems. Microorganisms found inside the xylem or growing in the holding solution resulted in a decrease in hydraulic conductivity of the stems, especially in the basal stem segment (van Doorn and de Witte, 1991). Bacteria found in the vase water belonged to the *Achromobacter*, *Alcaligenes*, *Bacillus*, *Escherichia*, *Flavobacterium*, *Micrococcus*, and *Pseudomonas* genera. Management of the 209 bacterial occlusions has been achieved with the use of anti-microbial, organic, and inorganic compounds—for example, vase solutions containing 2 or 10 µL L⁻¹ chlorine dioxide (ClO₂) extended the VL of *G. jamesonii* cv. Monarch and *L. asiaticum* cv. Vermeer inflorescences by preventing the population of bacteria to build up (Macnish et al., 2008). Pulsing of *G. jamesonii* cv. Ruikou flowers with 5 mg L⁻¹ nano-silver particles (NS) for 24 h resulted in VL extension and maintenance of inflorescences’ fresh weight (Liu et al., 2009). Similarly, pulsing *Gladiolus hybridus* inflorescences with 25 mg L⁻¹ of NS for 24 h significantly prolonged the VL and maintained the water balance (Li et al., 2017). Ascorbic acid solutions prolonged the VL of cut *G. grandiflorus* inflorescences from 5.75 to 12.5 days (Zulfqar et al., 2024a, b). The treatment with ascorbic acid significantly improved the relative fresh weight, floret diameter, number of open florets, and chlorophyll content.

Integrated disease management (IDM) that combines preharvest cultural controls with targeted postharvest treatments is now recognized as best practice. Preharvest strategies include irrigation scheduling to avoid prolonged canopy wetness, balanced nutrition, and the use of biocontrol agents such as *Trichoderma* and *Aureobasidium* to suppress latent infections (Garello et al., 2023). At postharvest, the use of defense elicitors—acibenzolar-S-methyl, methyl jasmonate, chitosan—induces systemic acquired resistance and reinforces cell wall barriers, slowing pathogen development without resorting solely to fungicides (Darras, 2018).

Recent advances in nanobiotechnology have yielded novel antimicrobial agents with low phytotoxicity. Silver nanoparticles (20–50 ppm) in combination with botanical elicitors such as aloe vera gel or essential oil nanoemulsions effectively inhibit both fungal and bacterial postharvest pathogens on cut *Chrysanthemum*, *Rosa*, and *Protea* stems while preserving stem hydraulic conductance and delaying wilting (Li et al., 2017).

Adoption of ecologically and environmentally friendly strategies may prevent the development of microorganisms in the vase solutions and enable the growers and sellers of the Australian

and South African ornamentals to deliver flowers with extended vase lives. Future research into host–microbe interactions may further improve postharvest quality control across the global floricultural supply chains.

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