



## Preservation of freshness in flowers: A review of post-harvest challenges and solutions for traditional flowers

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### ABSTRACT

Traditional flowers are those commonly grown and used in religious, cultural, and ceremonial settings mostly in loose form, but also including certain cut flowers that hold deep cultural significance. In countries like India, loose flowers such as marigold, jasmine, chrysanthemum, and rose are integral to religious rituals, festivals, and social ceremonies. High perishability of these flowers makes them suffer substantial post-harvest losses, estimated at 30–40% in India, primarily due to inadequate handling, storage, and transportation infrastructure. While pre-harvest factors such as cultivation practices, plant health, and pest management influence initial flower quality, post-harvest conditions play a pivotal role in determining their shelf life and marketability. Recent advances in post-harvest technology have provided promising solutions to mitigate these losses. Techniques such as pre-cooling, modified atmospheric packaging, and the application of floral preservatives and growth regulators have proven effective in delaying senescence and reducing ethylene-induced deterioration. Furthermore, innovative approaches, including the use of nano-materials, melatonin treatments, essential oils, and biodegradable coatings, are being explored for their potential to extend vase life, reduce microbial contamination, and maintain visual and olfactory attributes of the blooms. This review highlights both traditional practices and state-of-the-art interventions aimed at preserving the quality of harvested flowers, with an emphasis on scalable and sustainable technologies suitable for enhancing the longevity and commercial viability of traditional floral species.

**Keywords:** Marketing, Packaging, Perishable, Post-harvest, Shelf life, Traditional flowers

India's floriculture tradition is deeply rooted in its ancient cultural and religious practices, with classical texts and temple rituals emphasizing the symbolic and spiritual roles of flowers like jasmine, lotus, hibiscus, marigold, crossandra, and roses. These traditional flowers have long been integral to daily worship, festivals, weddings, and ayurvedic medicine, forming the backbone of India's floral heritage. Over time, the cultivation of these species has transitioned from informal backyard practices to organized commercial production, responding to increasing domestic demand and the ceremonial importance of loose flowers. Today, floriculture is a multi-billion-dollar industry focused on high-value ornamentals like cut flowers and potted plants, with India emerging as a major player in the global market (Varun and Lakshmi 2018a). As of 2023–24, India's floriculture covered 285,000 hectares, producing 2284,000 tonnes of loose flowers and 947,000 tonnes of cut flowers.

Karnataka, Tamil Nadu, Madhya Pradesh, and West Bengal are leading producers. In the same year, India exported floriculture products worth ₹717.83 Crores (USD 86.63 million) to markets including the USA, Netherlands, UAE, UK, and Canada (Sujani *et al.* 2022).

Traditional flowers are flowering plant species historically cultivated and widely used in India for religious, cultural, medicinal, ornamental, and ceremonial purposes primarily as loose flowers, but also including select cut flowers with deep cultural significance. Flowers like marigold, jasmine, chrysanthemum, rose, tuberose, crossandra, and lotus are prime examples (Pal *et al.* 2016). These can be grouped based on how they're used and the roles they play in traditions, which help guide discussions on how to best manage them after harvest. Due to their delicate nature and high moisture content, traditional flowers are prone to rapid spoilage. It's estimated that 20–30% of them are lost after harvest (Varun and Lakshmi 2018b), and in developing countries, this can go up to 50% (Salunkhe *et al.* 1990). Keeping flowers fresh from the field to the market depends on several factors like temperature, humidity, and cleanliness and if not managed well, these losses can be significant (Costa *et al.* 2021). The shelf life of flowers refers to their ability to stay fresh and

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visually appealing, is key to their value. Extending shelf life has major economic and social benefits like reduces waste, increases income for growers and sellers, improves export potential, and ensures people have access to fresh flowers for rituals and celebrations. It also helps to protect the livelihoods of small farmers and local vendors who rely on daily flower sales. Earlier, people used simple classical methods like hand sorting, keeping flowers in the shade, water, or wrapping them in paper to slow down wilting. These approaches are affordable and environmentally friendly, but they don't keep flowers fresh for long, especially when they need to be transported far or stored for several days. Contemporary techniques provide more effective means of prolonging flower life, including pre-cooling, cold storage, specialized packaging, and the application of floral preservatives, growth regulators, or antimicrobial agents. More recently, researchers have explored newer solutions like nanoparticles, melatonin treatments, essential oils, biodegradable coatings, and smart packaging. These methods help tackle common problems like ethylene damage, microbial growth, and water loss, and many have shown strong results in keeping flowers fresh longer. Still, they're not widely used in India mainly because of high costs, limited awareness, poor infrastructure, and scattered supply chains. Also, some chemical treatments raise safety and environmental concerns, so there's a growing interest in safer and more sustainable alternatives. This review aims to examine the post-harvest factors affecting the quality of traditional ornamental flowers, highlight the importance of shelf life extension, compare conventional and modern handling techniques, and emphasizing the need for scalable, eco-friendly, and region-specific solutions. By bridging this gap, the review seeks to contribute toward the sustainable growth of the floriculture sector in India and similar agro-climatic regions.

**Post-harvest quality of traditional flowers:** Globally produced flowers often face losses before reaching consumers due to suboptimal conditions, quality damage, pest infestation, and diseases. Inadequate cold chains and adverse environmental factors also impact quality. In India, post-harvest flower losses are estimated at 30–40% due to poor facilities whereas globally, one-third of food production is lost or wasted, equating to 1.3 billion tonnes annually (IGCC 2021). The vase and shelf life of flowers are influenced by pre-harvest, harvest, and post-harvest factors. Post-harvest factors are crucial for preserving quality and ensuring good condition upon delivery. Common issues include the absence of standardized maturity indices, improper handling, and shared storage. Flower taxonomy, chilling sensitivity, size, packaging requirements, and anatomical characteristics pose additional challenges. The developmental stage at excision impacts immediate quality and subsequent anthesis, with optimal stages both between and within species (Singh and Jain 2008). Long-distance transport necessitates earlier harvesting at the tight bud stage (Faust and Dole 2021).

An overview of the major causes contributing to post-harvest deterioration in loose flowers is illustrated in

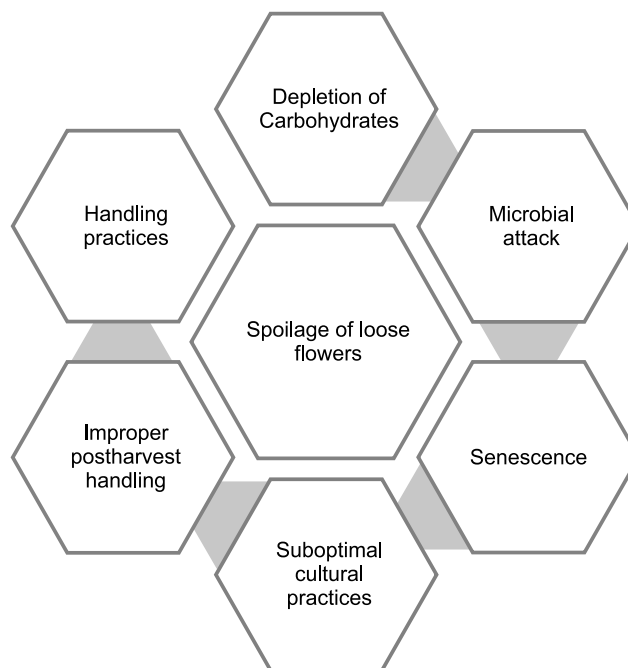


Fig. 1 Factors leading to spoilage of loose flowers.

Fig. 1, summarizing the key physiological, environmental, and handling-related factors affecting flower quality after harvest.

#### *Post-harvest factors affecting quality: Role of ethylene and storage conditions*

**Ethylene:** This natural plant hormone significantly impacts flower growth and ageing (Kou *et al.* 2021). Ethylene control is crucial for maintaining post-harvest quality during transit and storage. It can induce flower, leaf, and petal abscission, leaf yellowing, necrosis, and accelerated ageing (Aydin 2023). Ethylene sensitivity varies among species and air containing 100 ppb of ethylene is harmful for flowers (Pierik *et al.* 2006). Roses are highly ethylene-sensitive (Ha and In 2021), while marigolds show moderate sensitivity. Chrysanthemum and jasmine species exhibit specific ethylene responses affecting their post-harvest quality (Sukpitak *et al.* 2024). The ethylene sensitivity of some flower species as given by Bhattacharjee and De (2005) is summarized in Table 1.

**Storage conditions:** The primary function of storage in traditional flowers is to reduce metabolic activity through low temperatures, extending longevity (Marchioni *et al.* 2020). Temperature is the most critical factor in maintaining flower quality during storage (Jain *et al.* 2011, Singh *et al.* 2011). Lower storage temperatures decrease respiration, metabolic activity, ethylene synthesis, and disease development, increasing post-harvest durability (Hossain *et al.* 2020). Many species are stored at 0°C, just above freezing. However, post-storage issues can include non-opening buds, overblowing, colour deterioration, leaf yellowing, and decreased stem strength. Table 2 provides storage temperatures for various traditional flower species (Senapati *et al.* 2016).

Table 1 Classification of flower species based on ethylene sensitivity

Highly sensitive	Moderate sensitive	Insensitive
Rose, Jasmine, Tuberose, Carnation, Sweet Pea, Freesia	Marigold, Chrysanthemum, Crossandra, Gaillardia, Nerium, Stock, Snapdragon, Larkspur	Plumeria, Spider Lily, Orchid, Gladiolus, Dahlia, Gerbera, Daisy

Table 2 Optimal storage temperatures (°C) for various loose flower species

Flower species	Storage temperature (°C)	Flower species	Storage temperature (°C)
Rose	0–2	Nerium	10–12
Jasmine	4–7	Plumeria	12–14
Marigold	8–12	Spider Lily	8–10
Chrysanthemum	0–2	Carnation	0–2
Tuberose	4	Sweet Pea	0–2
Crossandra	10–12	Freesia	0–2
Gaillardia	4–7		

*Techniques for post-harvest maintenance of traditional flowers:* Post-harvest handling includes basic steps such as picking, cooling, sorting, packing, storing, and transporting flowers to get them ready for sale (Jain *et al.* 2015, Senapati *et al.* 2016). A large portion of flowers around 20–30% is lost after harvest due to outdated harvesting methods, poor infrastructure, and improper transport and packaging systems (Jain *et al.* 2006). Using better handling

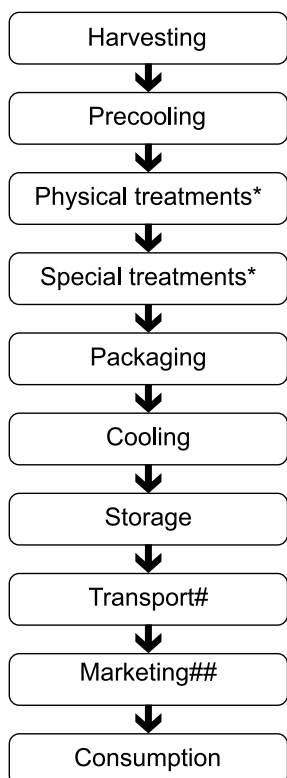


Fig. 2 General flow chart for post-harvest handling of loose flowers. \*Operations varies with each flower, # transport may be either import or export, ### Wholesale or Retail.

methods can reduce these losses, help flowers stay fresh and in good condition, and even increase their market value by 5–10 times (Jain *et al.* 2006). Some of the key methods used to improve the shelf life of loose flowers are shown in Fig. 2.

*Post-harvest physical treatments:* Post-harvest physical treatments help extend the shelf life of flowers by minimizing physiological deterioration. Common methods include pre-cooling, packaging, cold storage, controlled atmosphere storage, and conditioning with water. These techniques regulate temperature, humidity, and respiration rates, reducing wilting, thus maintaining floral freshness and quality during distribution.

*Pre-cooling:* Pre-cooling quickly lowers harvested flowers' temperature from 25–30°C to 1–2°C using methods like room cooling, hydro-cooling, vacuum cooling, and package icing. This reduces ethylene production, slowing ageing and minimizing wilting by decreasing transpiration (Brosnan and Sun 2001). The farmers use room and hydro cooling, vacuum cooling is most effective for fresh flowers at airports, while rapidly cooling them through water evaporation under low pressure (Varun and Lakshmi 2018b).

*Packaging:* After pre-cooling, flowers are packed with materials based on transport needs, reducing respiration and preventing heat buildup (Thakur 2020). Effective packaging protects flowers from damage, enhancing shelf life (Singh *et al.* 2022). Traditional methods, like bamboo baskets, are now being replaced by advanced options like cardboard and thermocol boxes for better flower preservation (Dey *et al.* 2022). For instance, jasmine packaging for export to Dubai, Singapore, and the USA has been standardized by TNAU, Coimbatore (Fig. 3).

Further, there are several studies and recommendations on how different flower species respond to various packaging methods and their average storage life (Table 3).

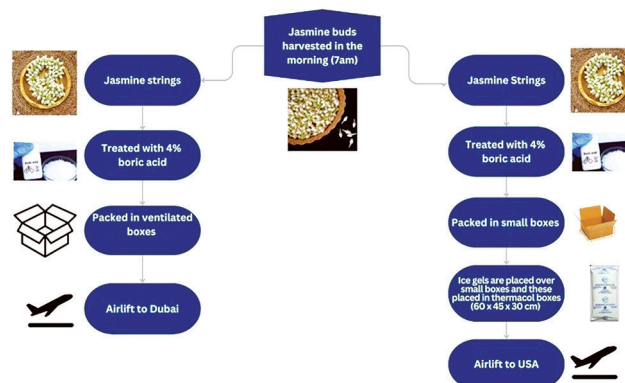


Fig. 3 Export packaging technology of Jasmine developed by TNAU, Coimbatore.

Table 3 Influence of packaging, storage, and temperature on quality of loose flowers

Crop	Type of package, Storage hrs/days, temperature	Responses	References
Chrysanthemum	Short-term controlled atmosphere (2 h, 5°C and 23°C)	Prolonged the shelf life	Burana <i>et al.</i> (2013)
	Polypropylene (200 gauge), 3 days + 6 h, 3–4°C	Minimized weight loss (%), flower diameter, and enhance shelf life	Srivastava <i>et al.</i> (2015)
	Wax paper wrapping and stored for 24 h at low temperature	Increased vase life, flower size, total sugars and reduced weight loss	Verma <i>et al.</i> (2006 and 2008)
Crossandra	Bulk packaging in polymeric film D955 within a CFB box	Flowers remained fresh for 72 h at ambient conditions and up to 96 h under cold storage	Bhuvanewari and Sangama (2020)
Rose	Wrapping of flowers of Cv. First Red in cellophane paper and stored in cold storage	Improved flower life and quality	Jain <i>et al.</i> (2005 and 2006 a)
	Modified atmosphere plastic containers (7.09 kPa CO <sub>2</sub> and 13.17 kPa O <sub>2</sub> ), 10 days, 2°C	Improved flower quality	Zeltzer <i>et al.</i> (2000)
	Controlled atmosphere (3% O <sub>2</sub> and 6% CO <sub>2</sub> ), 14 days and 21 days, 1°C	Increased flower quality, freshness of green foliage, and <i>Botrytis cinerea</i> incidence	Dias <i>et al.</i> (2017)
Jasmine	Polypropylene 60 µ packaging in CFB boxes with 4% ventilation	Extended shelf life up to 8 days at 7–8°C	Thamaraiselvi <i>et al.</i> (2010)
Marigold	Passive MAP (with or without ethanol) for 14 days	Increased levels of carotenoids and anthocyanins	Chrysargyris <i>et al.</i> (2018)
	200 Gauge polythene bags	Enhanced the shelf life and freshness	Panwar <i>et al.</i> (2020)
	Low-density polyethylene (LDPE) bags, 8 days of storage at 23°C	Significantly reduced weight loss and retained colour and appearance	Pal <i>et al.</i> (2016)
	Shrink-wrapping and high-density PE bags	Reduced weight loss, retained colour and increased storage duration up to 18 days under low temperature	Kumar <i>et al.</i> (2024)
	Shrink-wrapping and HDPE bags	Longest storability of 4.5 days and 19.0 days under ambient and cold storage, respectively	Viresh (2021), Jain <i>et al.</i> (2022)
Plumeria	Ice box, CFB boxes and polythene packaging	Overall flower quality was good	Verma and Jhanji (2022)
	Polyethylene pouches	Increased storage life upto 16 days under refrigerated conditions.	Kumar <i>et al.</i> (2019)
Tuberose	Polyethylene bag 200 gauge stored at 5°C	Enhanced storability upto 11 days with minimum weight loss	Singh <i>et al.</i> (2014)
	Pre-cooling at 4°C, and packaging in a CFB box lined with 100-gauge PE coating	Increased shelf life upto 15 days	Shil <i>et al.</i> (2017)
	Pre-treatment with 4% boric acid and packed in muslin cloth bags at 5°C	Longest shelf life, reduced respiration rate and lowest loss in weight (PLW)	Singh <i>et al.</i> (2022)

### Post-harvest chemical treatments

**Floral preservatives:** Floral preservatives are essential for improving colour, flower size, and shelf life in loose flowers (Rudnicki *et al.* 1991). These preservatives typically contain sugars like sucrose, which acts as a food source, slows protein degradation and maintains turgidity (Rani and Singh 2014). They are applied by spraying or dipping flowers to regulate senescence, control microbial growth, and support physiological processes. Preservatives are used mainly in the form of sprays or solutions for loose flowers. The impact of floral preservatives on the shelf life

of traditional flowers studied by various authors is given in Supplementary Table 1.

**Growth Regulators:** Growth regulators, including auxin, gibberellin, and cytokinin, control plant growth even at low concentrations. For instance, naphthyl phthalamic acid (NPA) inhibits auxin transport to reduce undesirable growth in spike flowers like gladiolus, while cytokinins delay leaf senescence (6-BA with STS reduces yellowing in chrysanthemums). New regulators like salicylic acid, polyamines, and nitric oxide extend flower life by reducing ethylene production and enhancing cell functions (Tatte *et al.* 2016).

**Ethylene scavengers:** Ethylene scavengers reduce ethylene gas in storage, delaying flower senescence. 1-MCP, an ethylene perception inhibitor, blocks ethylene binding sites, prolonging flower freshness (Hoppen 2020). For example, fumigation with EthylBloc improved rose display life, while Smart Fresh reduced ethylene production in cut flowers (Nergi and Ahmadi 2014). Silver thiosulfate (STS) is another common ethylene blocker used to prevent flower ageing (Jain *et al.* 2007).

**Cool chain management:** An efficient cold chain system starts on the farm and continues until the product reaches the customer. Cold chain management (CCM) offers a significant competitive advantage in floriculture. CCM requires precise temperature control and swift responses to fluctuations (Varun and Lakshmi 2018a). A cold chain is a network of facilities that maintain ideal storage conditions for perishable products like flowers, preserving quality from harvest to consumer. Proper temperature regulation is essential during packaging, transport, and storage to prevent value loss. Consistent temperature management, including rapid loading and unloading, reduces heat damage, ensuring high-quality flowers for consumers. A conceptual diagram representing the supply chain for traditional flowers is given in Supplementary Fig. 1.

#### *Advanced post-harvest techniques*

Post-harvest techniques are crucial for extending the shelf life and maintaining the quality of flowers, to meet consumer satisfaction. Several advanced methods, including physical, chemical, and emerging treatments like nanoparticles, melatonin, and essential oils, have been developed to enhance flower freshness (Supplementary Table 2). The following is an overview of these techniques and their applications:

**Nanoparticles:** Nanoparticles (NPs) are materials sized 1–100 nm, with silver nanoparticles (AgNPs) being the most common due to their antimicrobial, ethylene-inhibiting, and stomatal control properties. AgNPs are particularly effective in extending vase life by reducing fresh weight loss, suppressing microbial growth, and alleviating xylem blockages, thereby improving water uptake and petal turgidity (Solgi *et al.* 2009). Nanosilver particles have been shown to inhibit bacterial colonization and biofilm formation on flower stems, leading to better preservation (Naing and Kim 2020). Silver nanoparticles release ions that disrupt DNA replication and respiration in microbes, enhancing freshness (Mangaiyarkarasi and Haripriya 2019).

**Melatonin:** Melatonin is an indole derivative that influences seed germination, flowering, and protection against stress. It enhances post-harvest quality by boosting antioxidant enzyme activity, reducing oxidative stress, and stabilizing cell membranes, thereby prolonging vase life (Mazrou *et al.* 2022).

**Essential oils:** Essential oils derived from aromatic plants, exhibit antioxidant, antibacterial, and antifungal properties. They can control bacterial and fungal growth in flowers, extending shelf life (Solgi *et al.* 2009).

Phenolic compounds like carvacrol and thymol have strong antimicrobial activities, making EOs potential post-harvest treatments for flowers like *Gerbera jamesonii* (Solgi *et al.* 2009). However, their use in preserving loose flowers remains underexplored.

**Polyamines:** Polyamines are plant metabolites that delay senescence by acting as anti-senescent agents. Putrescine, spermidine, and spermine extend the shelf life of flowers like gerbera, rose, and chrysanthemum by regulating growth, development, and ripening processes (Khan *et al.* 2012). Their beneficial effects have been documented in various cut flowers (Vijayalaxami *et al.* 2024).

**Ozone:** Ozone (O<sub>3</sub>) is a reactive molecule that rapidly oxidizes microbial cells, damaging their DNA, membranes, and enzymes. Its strong oxidative properties make it effective for microbial control, thus improving the shelf life of flowers (Sivaranjani *et al.* 2021). Ozone's ability to kill microorganisms without leaving harmful residues makes it a valuable post-harvest treatment.

**Irradiation:** Irradiation sterilizes or eliminates organisms contaminating flowers, serving as a non-chemical alternative for quarantine treatments. It is particularly valuable in countries with strict regulations, such as Japan and the USA. Gamma radiation is widely used due to its deep penetration and energy levels, although higher doses may reduce vase life (Madhubala *et al.* 2022). Studies show that low-dose gamma radiation, combined with preservatives, significantly extends the shelf life of tuberose flowers (Ghosh *et al.* 2016).

**Electrolyzed water (EOW):** EOW, produced through the electrolysis of chloride-containing solutions, generates hypochlorous acid and reactive oxygen species, which inhibit microbial growth. Its use has been shown to extend the vase life of flowers like roses and gladiolus (Salisbury and Percival 2018). The low pH and chlorine compounds in electrolyzed water prevent bacterial contamination, making it a promising alternative to chemical preservatives (Ohta and Harada 2000).

**Genetic engineering:** Ethylene-sensitive flowers, like carnations and orchids, are prone to early senescence. Biotechnological methods, such as silencing the ACO gene, have been employed to extend vase life by reducing ethylene production (Savin *et al.* 1995). Transgenic carnations containing the *Arabidopsis etr1-1* gene have shown a threefold increase in vase life (Bovy *et al.* 1999). Further, reducing ethylene sensitivity in chrysanthemum and other species has improved post-harvest longevity (Sanikhani *et al.* 2008). Genetic engineering holds promise for extending the shelf life of traditional flowers, which are more susceptible to rapid senescence (Zakizadeh *et al.* 2013).

Traditional flowers, widely cultivated and utilized in India for cultural, religious, and commercial purposes, are highly perishable due to their delicate structure, high moisture content, and physiological sensitivity. Post-harvest losses, often reaching up to 30–40%, are primarily attributed to inadequate infrastructure, poor handling practices, and lack of access to advanced preservation technologies.

Extending the shelf life of these flowers is essential not only for reducing economic losses but also for ensuring consistent availability and quality for consumers. The post-harvest management must begin at the point of harvest and continue through storage, transport, and marketing. Maintaining the cold chain, adopting pre-cooling techniques, and using suitable packaging are critical steps in preserving freshness. Chemical preservatives containing sugars, germicides, and anti-ethylene agents play a vital role in delaying senescence and maintaining physiological quality. However, the environmental concerns associated with some conventional treatments such as silver thiosulphate, underscore the need for eco-friendly alternatives. Recent advances in physical treatments (e.g. LED light, ozone, gamma radiation) and the application of bioactive compounds like melatonin, polyamines, and essential oils offer promising results in improving flower longevity. Furthermore, the potential use of nanoparticles and plant-based formulations may serve as safer and more sustainable substitutes. Despite the availability of several technologies, their adoption in India remains limited due to high costs, lack of awareness, and infrastructural gaps. Future strategies should focus on standardizing low-cost, scalable post-harvest protocols suitable for traditional flowers and promoting research on varieties with improved post-harvest resilience. Integrating these approaches can significantly reduce spoilage, improve returns to producers, and support the sustainable growth of the floriculture sector.

#### REFERENCES

- Allwin V and Krishna K R. 2024. Endogenous plant metabolites influence on shelf-life extension of tuberose flowers. *Journal of Horticultural Sciences* (preprint).
- Arcega R A, Hou C Y, Hsu S C, Lin C M, Chang W H and Chen H L. 2022. Reduction effect of nonthermal plasma-activated water against pesticide residues and its impact on the quality of *Chrysanthemum morifolium* herbal flower. Available at SSRN 3999157.
- Asgari M, Azimi M H, Hamzehi Z, Mortazavi S N and Khodabandelu F. 2013. Effect of nano-silver and sucrose on vase life of Tuberose (*Polianthes tuberosa* cv. peril) cut flowers. *International Journal of Agronomy and Plant Production* 4: 680–87.
- Aydin V. 2023. Factors affecting the post-harvest quality of cut flowers. (In) *Advances Plant Research*, pp. 155–70, Akgul T A S (Ed.). IKSAD Publishing House, Turkey.
- Baidya B K, Chakrabarty S and Sethy P. 2020. Extending shelf life of loose tuberose florets (*Polianthes tuberosa* Linn. cv. Prajwal) by quick dipping in boric acid and sodium benzoate followed by low temperature storage. *International Journal of Chemical Studies* 8(3): 2607–12.
- Beni M A, Hatamzadeh A, Nikbakht A, Ghasemnezhad M and Zarchini M. 2013. Improving physiological quality of cut tuberose (*Polianthes tuberosa* cv. Single) flowers by continuous treatment with humic acid and nano-silver particles. *Journal of Ornamental and Horticultural Plants* 3(3): 133–41.
- Bhattacharjee S K and De L C. 2005. Senescence and post harvest physiology of cut flowers. (In) *Post-harvest technology of flowers and ornamental plants*, pp. 45–57. Pointer publishers, Jaipur, India.
- Bhuvanewari S and Sangama S. 2020. Standardization of packages for freshness retention and shelf-life extension of crossandra flowers under different storage conditions. *Plant Archives* 20(2): 09725210.
- Bovy A G, Angenent G C, Dons H J and van Altvorst A C. 1999. Heterologous expression of the Arabidopsis *etr1-1* gene in transgenic carnation confers ethylene insensitivity. *Molecular Breeding* 5: 301–08.
- Brosnan T and Sun D W. 2001. Precooling techniques and applications for horticultural products- A review. *International Journal of Refrigeration* 24(2): 154–70.
- Budiarto K, Zamzami L and Endarto O. 2022. Effect of salicylic and ascorbic acids on post-harvest vase life of chrysanthemum cut flowers. *Horticultural Science* 49(1).
- Burana C, Kurokura T and Yamane K. 2013. Short-term controlled atmosphere and 1-MCP effects on the vase life of cut flowers. *Acta Horticulturae* 1071: 635–39.
- Chrysargyris A, Tzionis A, Xylia P and Tzortzakis N. 2018. Effects of salinity on *Tagetes* growth, physiology, and shelf life of edible flowers stored in passive modified atmosphere packaging or treated with ethanol. *Frontiers in Plant Science* 9: 1765.
- Costa L C, de Araujo F F, Ribeiro W S, de Sousa Santos M N and Finger F L. 2021. Post-harvest physiology of cut flowers. *Ornamental Horticulture* 27(03): 374–85.
- Dey A, Pandey G and Rawtani D. 2022. Functionalized nanomaterials driven antimicrobial food packaging: A technological advancement in food science. *Food Control* 131: 108469.
- Dias G M, Santos L G, Cia P, Sigrist J M M and Honorio S L. 2017. Controlled atmosphere and refrigerated storage in cut roses 'Avalanche'. *Ornamental Horticulture* 23(3): 363–69.
- Doorn W G and Vaslier N. 2002. Wounding-induced xylem occlusion in stems of cut chrysanthemum flowers: Roles of peroxidase and catechol oxidase. *Post-harvest Biology and Technology* 26(3): 275–84.
- Faust J E and Dole J M. 2021. The global cut flower and foliage marketplace. *Cut Flowers and Foliages* 27: 1–47.
- Ghosh P K, Bhattacharjee P and Das S. 2016. Extension of shelf life of tuberose flowers using a combination of gamma irradiation and generally regarded as safe (GRAS) preservatives and assessment of antimicrobial potency of senesced flowers. *The Journal of Horticultural Science and Biotechnology* 92(2): 130–45.
- Ha S T T and In B C. 2021. Ethylene biosynthesis, signalling, and regulation in roses. *Flower Research Journal* 29(1): 1–10.
- Ha S T T, In B C and Lim J H. 2020. LED light improves post-harvest quality and longevity of cut rose flowers 'Lovely Lydia'. *Acta Horticulturae* 1291: 261–68.
- He S, Daryl C J, Donald E I and John D. Faragher. 2006. Stem end blockage in cut *Grevillea* Crimson Yul-lo inflorescences. *Post-harvest Biology and Technology* 41: 78–84.
- Hoppen C. 2020. 'Funktionelle und strukturelle Charakterisierung der Interaktion von Kupferchaperonen mit Ethylenrezeptoren'. PhD Thesis, Heinrich-Heine-University.
- Hossain A, Karim M and Juthee S A. 2020. Post-harvest physiological and biochemical alterations in fruits: A review. *Fundamental and Applied Agriculture* 5(4): 453–69.
- Indo-German Chamber of Commerce (IGCC). 2021. Master session on the prevention of post-harvest losses in India. <https://indien.ahk.de>
- Jahromi A K, Esehaghbeygi A, Sajadi S M, Nikbakht A, da Silva W,

- Sharifnabi B and Toghraie D. 2023. An application of dielectric barrier discharge treatment to control gray mold growth on cut rose flowers. *Journal of Stored Products Research* **104**: 102170.
- Jain Ritu and Janakiram T. 2016. Effect of aluminium sulphate and citric acid on post-harvest qualities of spray chrysanthemum (*Dendranthema × grandiflora*). *Current Horticulture* **4**(1): 42–47.
- Jain Ritu, Bhalla R and Dhiman S R. 2007. Effect of pulsing treatments on post-harvest life of rose cv. First Red. *Journal of Ornamental Horticulture* **10**(3): 143–47.
- Jain Ritu, Bhalla R, Gupta Y C, Thakur K S and Thakur R. 2006a. Effect of wrapping material and dry storage on post-harvest quality of rose cv. First Red cut flowers. *Journal of Ornamental Horticulture* **9**(3): 192–95.
- Jain Ritu, Bhalla, R, Gupta, Y C, Thakur, K S and Thakur R. 2005. Effect of wrapping materials and dry storage on post-harvest handling of rose cv. First Red. (In) *International Conference on Plasticulture and Precision Farming*, November 2005, New Delhi, pp. 189–17.
- Jain Ritu, Gupta Y C, Bhalla R and Thakur R. 2006. Effect of wet storage on post-harvest quality of rose cv First Red. *Journal of Ornamental Horticulture* **10**(4): 260–63.
- Jain Ritu, Gupta Y C, Bhalla R, Dhiman S R and Thakur R. 2006b. Standardization of holding solutions to increase the vase life of greenhouse grown rose cv First Red. (In) *Current Scenario in Temperate Horticulture*, pp. 489–95. Kishore D K, Sharma S K and Pramnik K K (Eds). New India Publishing Agency, New Delhi.
- Jain Ritu, Janakiram T and Kumawat G L. 2015. Studies on post-harvest attributes of tuberose cultivars as influenced by tinting with edible colours. *Current Horticulture* **3**(2): 18–24.
- Jain Ritu, Janakiram T, Singh K P and Kumawat G L. 2014. Effect of different floral preservatives on reducing foliage discolouration and increasing vase life of chrysanthemum (*Dendranthema × grandiflora*) cv White Reagan. *The Indian Journal of Agricultural Sciences* **84**(11): 86–88.
- Jain Ritu, Kumar V, Singh B and Tiwari A K. 2022. Screening of packaging materials to enhance the shelf life of marigold loose flowers. (In) *National Symposium on Ornamental and Edible Horticulture: Emerging Challenges and Sustainable Goals*, February 2022, West Bengal, pp. 21.
- Jain Ritu, Prasad K V and Singh O P. 2009. Effect of different floral preservative solutions on vase life of few chrysanthemum spray cultivars. *Journal of Ornamental Horticulture* **12**(4): 245–50.
- Jain Ritu, Prasad K V, Singh O P and Kumari G. 2008. Effect of different preservatives on vase life of few chrysanthemum cultivars. (In) *National Symposium on Recent Advances in Floriculture*, March 2008, Navasari, Gujarat, pp. 4.
- Jain Ritu, Singh K P and Namita. 2011. Effect of storage temperature and packing materials on display life of tuberose loose flowers. (In) *National Conference on Recent Trends and Future Prospects in Floriculture*, 5 March 2011, Meerut, Uttar Pradesh, pp. 174–75.
- Jain Ritu, T Janakiram and G L Kumawat. 2016. Efficacy of floral preservatives stored at different temperatures and time periods on lushness retention and vase life of chrysanthemum (*Dendranthema × grandiflora*) cv. Thai Chen Queen. *The Indian Journal of Agricultural Sciences* **86**(11): 1489–94.
- Kazempour S, Hashemabadi D and Kaviani B. 2013. Effect of silver nanoparticles on the vase life and quality of cut chrysanthemum (*Chrysanthemum morifolium* L.) flower. *European Journal of Experimental Botany* **3**(6): 298–302.
- Khan H A, Ziaf K, Amjad M and Iqbal Q. 2012. Exogenous application of polyamines improves germination and early seedling growth of hot pepper. *Chilean Journal of Agricultural Research* **72**(3): 429–33.
- Kim J H, Park S W and Lee Y B. 2023. Antimicrobial effect of slightly acidic electrolyzed (HOCl) water on *Botrytis cinerea* of cut rose flowers. *Horticultural Science and Technology* **41**(3): 304–14.
- Kou X, Feng Y, Yuan S, Zhao X, Wu C, Wang C and Xue Z. 2021. Different regulatory mechanisms of plant hormones in the ripening of climacteric and non-climacteric fruits: A review. *Plant Molecular Biology* **107**: 477–97.
- Kumar A, Gandhi N and Tinna D. 2019. Effect of different packaging material under different temperature conditions on physical properties and shelf life of rose (*Rosa indica*) and plumeria (*Plumeria alba*). *Journal of Pharmacognosy and Phytochemistry* **8**(1): 50–54.
- Kumar M N, Jain Ritu, Singh M C, Tiwari A K, Singh B, Sethi S and Madhavi K. 2024. Evaluation of packaging materials for enhancing the storage life of marigold flowers (*Tagetes erecta*). *The Indian Journal of Agricultural Sciences* **94**(2): 192–97.
- Madhubala R, Sujeeetha A R, Rajasri M, Sreedhar M, Geetha P and Gupta C S. 2022. Effect of gamma irradiation as phytosanitary treatment on vase life of white and pink carnation (*Dianthus caryophyllus* L.) cut flowers. *Mysore Journal of Agricultural Sciences* **56**(3): 161–69.
- Mangaiyarkarasi R and Haripriya S. 2019. Study on advance storage and chemical treatments to enhance the shelf life of tuberose. *The Pharma Innovation Journal* **8**(7): 618–19.
- Mangave B D. 2014. 'Standardization of post-harvest technology of spider lily (*Hymenocallis littoralis* L.) for distant market'. PhD Thesis. Navsari Agricultural University, Navsari, Gujarat.
- Manimaran P, Ganga M, Kannan M and Arulmozhiselvan K. 2018. Standardization of post-harvest management techniques for *Jasminum nitidum* flowers. *Chemical Science Review and Letters* **7**(26): 652–58.
- Marchioni I, Pistelli L, Ferri B, Copetta A, Ruffoni B, Pistelli L and Najar B. 2020. Phytonutritional content and aroma profile changes during post-harvest storage of edible flowers. *Frontiers in Plant Science* **11**: 590968.
- Mazrou R M, Hassan S, Yang M and Hassan F A. 2022. Melatonin preserves the post-harvest quality of cut roses through enhancing the antioxidant system. *Plants* **11**(20): 2713.
- Mohanasundari P, Sivakumar T and Krishna Surendar K. 2018. Effect of post-harvest treatment and storage temperature on fragrance of Jasmine (*J. grandiflorum*). *Annals of Plant Sciences* **7**(8): 2391–93.
- Naing A H and Kim C K. 2020. Application of nano-silver particles to control the post-harvest biology of cut flowers: A review. *Scientia Horticulturae* **270**: 109463.
- Nergi M A D and Ahmadi N. 2014. Effects of 1-MCP and ethylene on post-harvest quality and expression of senescence-associated genes in cut rose cv. Sparkle. *Scientia Horticulturae* **166**: 78–83.
- Ohta K and Harada K. 2000. Effect of electrolyzed anode water on the vase life of cut rose flowers. *Journal of the Japanese Society for Horticultural Science* **69**(4): 519–22.
- Pal S, Kumar Ghosh P and Bhattacharjee P. 2016. Effect of packaging on shelf-life and lutein content of marigold (*Tagetes erecta* L.) flowers. *Recent Patents on Biotechnology* **10**(1): 103–20.
- Panwar S, Singh K P, Jain Ritu, Janakiram T and Kumar P. 2020. Standardization of different packaging materials and storage

- conditions for enhancing the shelf-life of loose flowers of African marigold (*Tagetes erecta* L.). *Journal of Ornamental Horticulture* **23**(1): 36–40.
- Pierik R, Tholen D, Poorter H, Visser E J and Voeseek L A C J. 2006. The Janus face of ethylene: Growth inhibition and stimulation. *Trends in Plant Science* **11**: 176–83.
- Priya B B, Krishan P S, Jain Ritu, Shruti Sethi and Lakshmi S. 2022a. Shelf life of tuberose loose flowers as influenced by different packaging materials. (In) *5<sup>th</sup> International Conference on Advances in Smart Agriculture and Biodiversity Conservation for Sustainable Development*, 4 March 2022, Jaipur, Rajasthan, pp. 139.
- Priya B B, Krishan Pal Singh, Jain Ritu, Shruti Sethi and Lakshmi S. 2022b. Response of floral preservative treatments on shelf life of tuberose loose flowers. (In) *5<sup>th</sup> International Conference on Advances in Smart Agriculture and Biodiversity Conservation for Sustainable Development*, March 2022, Jaipur, Rajasthan, pp. 139–40.
- Rani P and Singh N. 2014. Senescence and post-harvest studies of cut flowers: A critical review. *Pertanika Journal of Tropical Agricultural Science* **37**(2): 58–63.
- Rezai S, Nikbakht A, Zarei H and Sabzalian M R. 2023. Physiological, biochemical, and post-harvest characteristics of two cut rose cultivars are regulated by various supplemental light sources. *Scientia Horticulturae* **313**: 111934.
- Rudnicki R M, Nowak J and Goszczynska D M. 1991. Cold storage and transportation conditions for cut flowers cuttings and potted plants. *Acta Horticulturae* **298**: 225–36.
- Salisbury A M and Percival S L. 2018. The efficacy of an electrolysed water formulation on biofilms. *Advances in Experimental Medicine and Biology* **1214**: 1–8.
- Salunkhe D K, Bhat N R and Desai B B. 1990. *Post-harvest Biotechnology of Flowers and Ornamental Plants*. Springer Verlag, Berlin.
- Sanikhani S, Frello S and Serek M. 2008. Genetic engineering of ethylene sensitivity in *Kalanchoe blossfeldiana* and its impact on plant shelf life. *Journal of Plant Growth Regulation* **27**(2): 117–23.
- Savin K W, Baudinette S C, Graham M W, Michael M Z, Nugent G D, Lu C Y and Cornish E C. 1995. Antisense ACC oxidase RNA delays carnation petal senescence. *Horticultural Science* **30**(5): 970–72.
- Senapati A K, Raj D, Jain Ritu and Patel N L. 2016. Advances in packaging and storage of flowers. *Commercial Horticulture* **34**: 473–88.
- Shil S, Chakrabarty S and Kuchi V S. 2017. Influence of post-harvest treatments on quality of loose flowers of *Polianthes tuberosa* Linn. cv. Prajwal. *International Journal of Current Microbiology and Applied Science* **6**(7): 440–48.
- Shinde S P, Chaudhari S R and Matche R S. 2023. A way forward for a sustainable active packaging solution for prolonging the freshness and shelf life of *Rosa hybrida* L. cut flowers. *Post-harvest Biology and Technology* **204**: 112475.
- Shravan P. 2017. 'Studies on senescence in gerbera using nanoparticles and botanicals'. PhD Thesis. Indian Agricultural Research Institute, New Delhi.
- Singh K P and Jain Ritu. 2008. Effect of harvesting stage on post-harvest handling of tuberose cv. Prajwal. (In) *National Symposium on Recent Advances in Floriculture*, 4–6 March 2008, Navasari, Gujarat, pp. 45.
- Singh K P, Jain Ritu, Panwar S, Kumari P and Verma P K. 2014. Effect of packaging materials and storage conditions on shelf life of loose flowers of tuberose. *Journal of Ornamental Horticulture* **17**(1): 54–58.
- Singh K P, Priya B B, Jain Ritu, Sethi S and Nair E S. 2022. Enhancing shelf life of loose flowers of tuberose (*Polianthes tuberosa* Linn.) using preservatives and packaging materials. *Annals of Agriculture* **15**(2): 210–16.
- Singh K P, Jain Ritu and Namita. 2011. Effect of chemical preservatives and storage conditions on shelf life of loose flowers of tuberose. (In) *National Conference on Recent Trends and Future Prospects in Floriculture*, 5 March 2011, Meerut, Uttar Pradesh, pp. 174.
- Sivaranjani S, Prasath V A, Pandiselvam R, Kothakota A and Khaneghah A M. 2021. Recent advances in applications of ozone in the cereal industry. *Food Science and Technology* **146**: 111412.
- Solgi M, Kafi M, Taghavi T S and Naderi R. 2009. Essential oils and silver nanoparticles (SNP) as novel agents to extend vase-life of Gerbera (*Gerbera jamesonii* cv. 'Dune') flowers. *Post-harvest Biology and Technology* **53**(3): 155–58.
- Srivastava R, Sharma G and Chand S. 2015. Post-harvest life of cut chrysanthemum cultivars in relation to chemicals, wrapping material and storage conditions. *Journal of Horticulture* **2**(1): 48–53.
- Sujani C, Chittibabu U L S S, Varaprasad Y, Meghana Y and Rao M T. 2022. Floriculture - A review. *Journal of Global Trends in Pharmaceutical Sciences* **3**(3): 9990–95.
- Sukpitak C, Seraypheap K, Munoz P and Munne-Bosch S. 2024. Influence of water deficit on the longevity of ethylene-sensitive and ethylene-insensitive flowers. *Environmental and Experimental Botany* **29**: 105647.
- Tatte S, Singh A and Ahlawat T R. 2016. Effect of polyamines and natural growth substances on the growth and flowering of rose (*Rosa hybrida*) cv. Samurai under protected conditions. *Journal of Applied and Natural Science* **8**(3): 1317–20.
- Thakur N. 2020. A review on the effect of storage methods and packaging material on the post-harvest longevity of cut flowers. *International Journal of Chemical Studies* **8**(3): 2375–79.
- Thakur R, Gupta, Y C, Dhiman S R, Bhalla R and Jain Ritu. 2006. Performance of rose cv First Red under naturally ventilated polyhouse conditions in the mid hills of Himachal Pradesh. (In) *Current Scenario in Temperate Horticulture*, pp. 301–05. Kishore D K, Sharma S K and Pramnik K K (Eds). New India Publishing Agency, New Delhi.
- Thamaraiselvi S P, Jawaharlal M, Ganga M and Varadharaju N. 2010. Packaging technology for long term storage of jasmine (*Jasminum sambac* Ait.) flowers. *Journal of Ornamental Horticulture* **13**(3): 171–81.
- Varun H and Jain Ritu. 2018. Effect of ascorbic acid on leaf discolouration and vase life of spray chrysanthemums. *Journal of Hill Agriculture* **9**(3): 274–77.
- Varun H and Jain Ritu. 2021. Ascorbic acid for reducing foliage discolouration in cut chrysanthemum. *Indian Horticulture* **66**(3): 7–9.
- Varun H and Lakshmi D M. 2018a. Post-harvest management, processing and value addition of cut flowers. (In) *Advances in Post-harvest Management, Processing and Value Addition of Horticultural Crops Part 1: Fruits and Flower Crops*, pp. 527–73.
- Varun H and Lakshmi D M. 2018b. Post-harvest treatments to enhance vase life of cut flowers. (In) *Trends and Prospects in Post-harvest Management of Horticultural Crops*, pp. 483–511. Mitra S, Banik A K, Mani A, Kuchi V S and Meena N K (Eds).

- Today and Tomorrow's Printers and Publishers, New Delhi.
- Varun H, Jain Ritu, Arora A, Jain N, Swaroop K, Singh M K and Kumar G. 2018a. Delaying petal and leaf senescence in Yellow Star chrysanthemum using ascorbic acid. *Indian Journal of Horticulture* **75**(3): 506–11.
- Varun H, Jain Ritu, Neelu J, Arora A, Swaroop K, Singh M K, Kumar P and Kumar G. 2018b. Quantification of total endogenous ascorbic acid from chrysanthemum cultivars and its association with post-harvest life. *The Indian Journal of Agricultural Sciences* **88**(9): 1429–33.
- Verma A K, Gupta Y C, Dhiman S R and Jain Ritu. 2006. Effect of dry storage on post-harvest quality of chrysanthemum (*Dendranthema grandiflora* Tzevlev.) cv. Snow Ball. *Journal of Ornamental Horticulture* **9**(1): 25–28.
- Verma A K, Gupta Y C, Dhiman S R and Jain Ritu. 2008. Dry storage of chrysanthemum: Effect on quality. *Floriculture Today* **13**(4): 28–34.
- Verma T and Jhanji S. 2022. Evaluation of post-harvest quality of marigold flowers after packaging and storage in different seasons. *Bangladesh Journal of Botany* **51**(2): 247–54.
- Vijayalaxami M A, Rao M, Swathi K and Kumar P A. 2024. Effect of polyamines on post-harvest physiology and vase life of cut gerbera. *International Journal of Plant and Soil Science* **36**(4): 216–23.
- Viresh M B, 2021. 'Enhancing the storage life of marigold (*Tagetes erecta* L.) flowers using preservatives and packaging materials'. MSc Thesis. ICAR-Indian Agricultural Research Institute, New Delhi.
- Wu Y, Wang Y, Wang S, Fan X, Liu Y, Zhao R and Zou J. 2023. The combination of graphene oxide and preservatives can further improve the preservation of cut flowers. *Frontiers in Plant Science* **14**: 1121436.
- Zakizadeh H, Tohidfar M and Jalali F. 2013. Enhanced vase life of transgenic Rose 'Linda' expressing *PSAG12-ipt* gene. *Journal of the American Society for Horticultural Science* **138**(3): 195–200. doi:10.21273/JASHS.138.3.195
- Zeltzer S, Meir S and Mayak S. 2000. Modified atmosphere packaging (MAP) for long-term shipment of cut flowers. *Acta Horticulturae* **553**: 631–34.
- Zhang H, Xi J, Liu Z, Chen M, Lu Z, Xue H and Bi Y. 2023. Isolation and identification of pathogens causing blue mold of Lanzhou lily during post-harvest storage and control of disease and mycotoxin accumulation by ozone treatment. *Journal of Fungi* **9**(11): 1091.