Journal of Advances in Biology & Biotechnology

Volume 27, Issue 12, Page 36-45, 2024; Article no.JABB.127693
ISSN: 2394-1081

Innovative Eco-friendly Approaches to Enhance the Vase Life of Cut Flowers: A Comprehensive Review

Mukesh Kumar [a*], Ravi Kumar [a*], Rishubh Motla [a], Mahima Sharma [a], Devanshu Shukla [a], Krishna Kaushik [a] and Rajat Singh [b]

[a] College of Horticulture, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, UP-250110, India.
[b] School of Agriculture, Uttranchal University, Dehradun, Uttrakhand-248007, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jabb/2024/v27i121753

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/127693

Review Article

Received: 03/10/2024
Accepted: 05/12/2024
Published: 09/12/2024

ABSTRACT

This study investigates the key determinants of cut flower vase life, focusing on the influence of pre- and post-harvest conditions and environmental factors. Addressing the commercial challenges associated with limited vase life, the research underscores the critical need for sustainable and eco-friendly floral preservatives to enhance flower freshness. It highlights the rising interest in plant-based extracts and biodegradable alternatives as effective substitutes for conventional chemical preservatives. These natural preservatives not only improve floral longevity but also reduce environmental impact when paired with optimized post-harvest management practices. The study emphasizes the growing body of research dedicated to extending the shelf life of cut flowers

**Corresponding author: E-mail: ravikm4@gmail.com; k.mukesh123@yahoo.com;*

Cite as: *Kumar, Mukesh, Ravi Kumar, Rishubh Motla, Mahima Sharma, Devanshu Shukla, Krishna Kaushik, and Rajat Singh. 2024. "Innovative Eco-Friendly Approaches to Enhance the Vase Life of Cut Flowers: A Comprehensive Review". Journal of Advances in Biology & Biotechnology 27 (12):36-45. https://doi.org/10.9734/jabb/2024/v27i121753.*

through environmentally conscious solutions. By advancing both flower durability and ecological sustainability, eco-friendly preservatives hold significant potential to revolutionize the floriculture industry.

Keywords: Eco-friendly preservatives; vase life; floriculture industry; cut flowers.

1. INTRODUCTION

Flowers are special, highly developed organs that help angiosperms, or blooming plants, reproduce as successfully as possible. Sepals, petals, stamens, and carpels are the four distinct whorls that make up a typical angiospermic flower. Among them, pollinators are drawn to petals, which facilitates pollination (Glover and Martin, 1998; Ma et al., 2018). They are therefore significant from a biological and aesthetic standpoint. However, unlike stamens and carpels, petals do not actively contribute to reproduction. One of the most valued horticultural products is cut flowers. Maintaining cut flowers of the highest quality and extending their shelf life are both practical and necessary for having the best items available in marketplaces (Redman et al., 2002; Macnish et al., 2008). The term "vase life" describes how long a cut flower will look good in a vase. For this reason, it is the most crucial characteristic of decorative crops, such as roses, that are used as cut flowers. Flowers open and attract flavor in the early stages of vase life. Over time, they experience senescence, dehydration, and petal abscission. Additionally, cut flowers are susceptible to postharvest diseases, such as gray mold caused by the necrotrophic fungus *Botrytis cinerea*. All of these physiological changes, which include the balance of phytohormones in the flower and the up- or down-regulation of many genes in different hormone pathways, take place at a certain period and in a highly coordinated manner.

Ethylene, which speeds up the senescence of many flowers, and microorganisms that induce vascular blockage, which shortens the shelf life of cut flowers, are the two primary variables that impact the vase life of cut flowers (Zencirkiran, 2005, 2010). Furthermore, cut flowers are regarded as a national revenue source, particularly in nations with favorable growing and blossoming conditions. One of these nations is Egypt, which has a variety of production factors, including as soil, light, humidity, and temperature, that allow for the cultivation and production of high-quality and abundant flower crops (Amin, 2017). Cut flower crops like gladiolus and tuberose have been the subject of several research, such as those by Kumar et al. (2022, 2023, 2024) and Sharma et al. (2024), which have provided insightful information on the vase life of their cut flowers. Furthermore, biotechnological methods including artificial miRNAs (Kumar et al. 2024), RNA interference (RNAi) techniques (Kumar et al. 2024a), and CRISPR/Cas9 technology (Sirohi et al. 2022) might prolong the vase life of floricultural crops. Due to the growing consumer demand, floriculture has been viewed as a competitive business in a number of nations in recent decades, with significant economic potential (Younis et al. 2018). Many floriculture researchers across the world are primarily interested in delaying the senescence of cut flowers in order to extend their vase life. Thus, maintaining the postharvest quality of flowers is a crucial issue and a significant obstacle florists must overcome in order to provide their customers with high-quality, long-lasting flowers (Hassan and Schmidt, 2004; Mazrou et al. 2022). Preserving the quality of cut flowers is a crucial issue and continues to be the biggest obstacle facing florists throughout the globe. In order to prolong the vase life, some floriculture specialists are concentrating on postponing the senescence of flowers. Therefore, postharvest technology's primary objective is to provide consumers with high-quality, long-lasting flowers (Scariot et al., 2014). Since the products in issue are not eaten, concerns regarding the uncontrolled use of synthetic chemicals are frequently ignored. The negative impacts of excessive chemical usage on the environment and the health of flower workers have been brought to light by a number of studies conducted in major flower marketplaces in Europe, Africa, and other nations. Concern over using fewer toxic chemicals in food crops and switching to organic agriculture is rising these days, and this is also true for the decorative plant industry. To prevent related health effects, the use of dangerous chemicals including silver-thiosulphate (STS), silver nitrate ($AgNO3$), aluminum and cobalt compounds, hydroxy quinoline, and thiabendazole (TBZ) should be minimized during post-harvest processing of flower harvests. It is necessary to investigate safe and efficient natural substitutes for toxic chemicals in vases. Singh et al. (2022) outlined the various chemicals' roles in prolonging the life of cut flowers as well as the hazards involved. Herbal extracts have the potential to lessen the usage of pesticides in cut flower handling, according to many research.

The review addresses pre-harvest and post-harvest circumstances, among other factors that affect cut flowers' vase life. It draws attention to how floral preservatives help cut flowers last longer, with a focus on the rising need for sustainable and environmentally friendly substitutes. Plant-based floral preservatives have become a viable option in recent years, providing a practical and eco-friendly way to extend vase life. In order to extend the shelf life of cut flowers while reducing their negative effects on the environment, researchers are concentrating more and more on creating these natural preservatives. Here, we provide a brief overview of some cut flowers like tuberose gladiolus, carnations, gerbera and chrysanthemums.

2. THE CUT FLOWERS

2.1 Tuberose

Polianthes tuberosa Linn. is a popular commercial bulbous ornamental plant due to its stunning long spikes, high cut-flower production, and year-round availability of blooms in tropical and subtropical locations (Sirohi et al., 2017). Tuberose is cultivated primarily for the flower's attractive and powerful scent (Kumar et al. 2021).

2.2 Carnation

It is commonly known that carnations (*Dianthus caryophyllus* L.) come in a variety of colors and forms. It is in great demand and is among the top 10 cut flowers worldwide (Hashemabadi et al. 2015). The caryophyllaceae family includes carnations. Cut flowers (*Dianthus caryophyllus*), pot flowers (*Dianthus carthusianorum* L.), and garden flowers (*Dianthus barbatus* L.) are among its three species.

2.3 Roses

Rosa hybrida L., members of the Rosaceae family, are among the most economically significant cut-flower plants. These valuable ornamental plants are commonly used as potted or cut flowers across the world. However, their limited commercial worth appears to be due to the inferior quality and relatively short lifespan of cut flowers following harvest.

2.4 Gladiolus

Gladiolus grandiflorus is one of the most popular and expensive bulbous cut flowers. The lowermost floret opening and its colour appearance are the primary indicators of spike harvesting (Wahocho et al., 2016). Gladiolus is a popular cut flower crop because to its magnificent spike of bright, graceful, and appealing florets. Gladiolus has a spike inflorescence that is often cut after just a few florets are open, and the life of such spike is determined by both floret life and the opening of the enduring spike florets (Ezhilmathi et al., 2007). Cut gladiolus has a limited life span due to physiological and biochemical factors that cause senescence.

2.5 Gerbera

The Transvaal or Barbeton daisy, or Gerbera (*Gerbera jamesonii* L.), is a member of the Asteraceae family and originated in Africa. Its glossy ray florets and variety of forms and colours make it one of the most sought-after cut flowers on the international market (Darras, 2021). But because they suffer from a variety of postharvest damages, including dehydration, xylem blockage, temperature fluctuations, fungi, mechanical impairment, and bacterial attachment, many of these highly valued cut flowers have a short vase life and only stay fresh for a short time (Ahmad et al., 2017).

2.6 Chrysanthemum

The chrysanthemum, or *Dendronthema grandiflora*, is referred to as the "Queen of the East." In the global market, chrysanthemums are ranked second only to roses. The flower's aging process quickens once it separates from its mother plant and continues to carry out functions including breathing and transpiration. Postharvest treatment is essential to slow down their aging process and, in turn, extend their vase life (Tsegaw et al., 2011). One of the most significant issues with cut flowers is their short postharvest life. One of the most popular ways to extend the vase life of cut flowers is to add vase preservatives to vase solutions.

3. THE CUT FLOWERS AND VASE LIFE

Flowers and flower buds that have been cut from their parent plant, generally together with some stem and leaf, are known as cut flowers. It is removed for cosmetic reasons from the plant. Since these are living tissues with a high metabolic activity, flowers that are separated from their mother plants senescent more quickly because the water and nutrients flowing from the roots to the flower parts are disrupted (Sharma and Sarkar, 2018). Additionally, flowers that are separated from their mother plants have a very short shelf life (Solgi et al., 2009). Vase life is the amount of time that a bouquet or any group of cut flowers retains its aesthetic value and appeal after standing in calm water. While delicate flowers, such as roses, have a limited container life of only a few days, carnations have a very extended vase life—up to several weeks.

3.1 Factors Affecting Vase Life

Features including floret diameter and length, flower opening, fresh weight variations, stem or pedicel diameter or length, senescence pattern, petal colour, overall lifespan, and leaf folding are used to calculate vase life (De et al. 2015). The vase life and postharvest quality of cut flowers are influenced by a number of factors, including preharvest and postharvest (Nguyen et al., 2020; Kumar et al., 2022). Temperature, harvesting time, water intake, water quality, and ethylene levels are a few of them (Fig.1). The examination of pre- and post-harvest variables influencing cut flower vase life has been the focus of several efforts, some of which are included below.

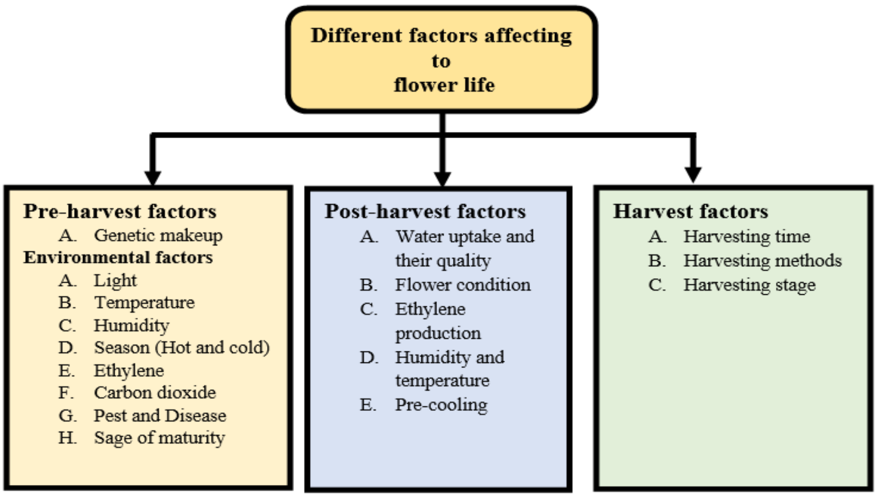

Fig. 1. Factors affected the cut flower vase life

Table 1. A list of key pre-harvest and post-harvest factors influencing flower shelf life

Factors Name	Pre-Harvest phase	Post-Harvest phase
Temperature	Environmental temperature during growth	Storage temperature and transport conditions
Water Management	Soil moisture and irrigation practices	Water quality and hydration methods post-harvest
Ethylene Exposure	Exposure to ethylene during growth	Ethylene exposure during storage and transportation
Light Conditions	Light exposure and day length during growth	Light conditions during storage (e.g., darkness)
Nutrient Availability	Fertilizer and soil nutrient levels	Nutrient supply in post-harvest solutions
pH Levels	Soil pH influencing plant growth	pH levels of storage and preservation solutions
Genetic Factors	Flower variety and cultivar	Post-harvest treatments and genetic characteristics
Harvest Timing	Stage of maturity at harvest	Delayed harvesting or early harvesting impacts shelf life
Water Absorption	Root health and absorption efficiency	Post-harvest water uptake and hydration techniques
Mechanical Damage	Handling and transport before harvest	Damage during post-harvest handling and transportation

Table 2. A list of used eco-friendly floral preservatives on cut-flower crops

Cut-flower crops	Name of eco-friendly floral preservatives	References
Gladiolus	Ethanolic extract of *Piper betle* leaf (PbLE)	Datta et al. (2016)
Gladiolus	*Moringa leaf* extract (MLE)	Hassan and Fetouh (2019)
Roses	*Moringa* leaf extract (MLE) or *moringa* seed extract (MSE)	Hassan et al. (2020)
Gladiolus	*Moringa olifera*, *Mentha piperita*, and *Calotropis procera* leaf extracts	Akhtar et al. (2021)
Carnation	Salicylic acid and leaves extract of *Salix* and *Mentha*	Dehestani-Ardakani et al. (2022)
Chrysanthemums	Artemisia, ocimum, geranium, and rosemary oils	Nirmala et al. (2023)
Gladiolus	Lemon grass (LG) essential oil	Thakur et al. (2023)
Gerbera	Green tea extract (GTE) and cinnamon powder extract (CPE)	Jamja et al. (2024)
Gladiolus	Sage and rosemary essential oils (EOs)	Moussa et al. (2024)

3.2 Pre-harvest and Post-harvest Factors

Numerous pre-harvest (before harvest) environmental conditions, such as temperature, light, humidity, ethylene, carbon dioxide, and others, reduce the vase life of cut flowers (Kumar et al. 2002). The post-harvest elements that impact the vase life of cut flowers. Temperature, ethylene concentration, pH, water quality, water absorption, and harvest timing are critical factors affecting the outcomes. Table 1 outlines the pre-harvest and post-harvest factors affecting flower shelf life.

Cut flowers are currently a source of export income for the global floriculture industry. Each cut flower type has a different vase life, and the methods and circumstances employed before to, during, and following harvest all have an impact on how long the flowers remain fresh. The floral industry places a high priority on factors that affect postharvest quality and vase life, which are necessary to produce the desirable qualities of cut flowers.

4. EFFECTIVE, ECO-FRIENDLY AND SUSTAINABLE FLORAL PRE-SERVATIVES FOR CUT FLOWER VASE LIFE

To achieve the desired characteristics of cut flowers, postharvest quality and vase life must be taken into account, and the floral business places a high value on elements that influence these aspects. Using floral preservation solutions is a smart way to extend cut flowers' vase life. Nowadays, Eco-friendly floral preservation solutions that prolong the vase life of cut flowers have been shown to be less expensive and more natural than chemical alternatives. Nevertheless, there are several issues with using eco-friendly and chemical remedies. Cut flower crops like gladiolus and tuberose and others have been the subject of several studies which are listed in Table 2.

In this paper, we address the best options for holding-preservative-solution practices and provide an overview of a number of possible strategies to extend the vase life of flowers. Thyme, Rosemary, Geranium, Mint, Eucalyptus, Ajowan, Savory, Coriander, Dill, and *Piper betle* leaf extracts are among the essential oils and herbal extracts that are often examined. For example, when essential oil was tested on cut flowers of lisianthus, gerbera, chrysanthemum, alstroemeria, gladiolus, rose, and carnation, favorable results were obtained regarding the longevity of the cut flowers. Most research found that essential oils and herbal extracts were effective in floriculture as a noble alternative to other metal and chemical compounds because to their antibacterial properties and eco-friendliness (Kantharaj et al. 2018). Datta et al. (2016) described a cost-effective, environmentally friendly, and highly reproducible method for the large-scale synthesis of silver nanoparticles (SNPs) by reduction process using an ethanolic extract of *Piper betle* leaf (PbLE), where the PbLE acts as a reducing and stabilizing agent with an antimicrobial property. This extract is used for the green synthesis of *Piper betle* silver nanoparticles (PbSNPs) to prepare commercial vase solution. They conducted an investigation into the impact of PbSNPs on the post-harvest physiology (effect on antioxidant enzymes, vascular blockage, and vase life of gladiolus cut-spikes) in relation to the 5-SSA (used as a positive control) in order to determine the best vase solution for extending its vase life. The potential of *moringa leaf* extract (MLE) as a postharvest preservation solution to enhance the quality and durability of gladiolus spikes was examined by Hassan and Fetouh (2019). Gladiolus spikes were exposed to different MLE concentrations in vase solution (0, 1, 2, 3, 4%). When 3% MLE was applied, the vase life was 10 days longer than the control, and this was the case for all MLE concentrations. The effects of MLE were more noticeable at 3% concentration, and the duration and quality of cut gladiolus spikes were not improved at higher levels. According to Hassan and Fetouh (2019), MLE demonstrated these benefits by preserving photosynthetic pigments and water relations while reducing the oxidative stress caused in the cut spike. Similarly, Hassan et al. (2020) investigated whether *moringa* leaf extract (MLE) or *moringa* seed extract (MSE) might be used as a natural preservative to increase the vase life of cut roses. Both applications were chosen and evaluated since they are natural and pose no environmental risk. Cut flowers of *Rosa hybrida* cv. 'Upper Class' were pulsed overnight in MLE or MSE at 1:40, 1:30, 1:20, and 1:10 (extract/water, v/v) before being transferred to distilled water. MLE or MSE greatly prolonged vase life, particularly with the 1:30 and 1:20 extracts. MLE and MSE lasted 8 and 5 days, respectively, longer than untreated flowers. Hassan et al. (2020) concluded that MLE and MSE treatments significantly prolonged the vase life of cut roses by optimizing water balance and enhancing antioxidant activity, with MLE demonstrating superior effectiveness. Consequently, MLE is suggested as a potential preservative for advancing practices in the floral industry. Moreover, Akhtar et al. (2021) aimed to determine if natural plant extracts might be used as efficient preservatives to increase the postharvest vase life of gladiolus spikes. There is no evidence in the literature that *Calotropis procera* leaf extract has been used as a vase-life extender for cut flowers, despite the fact that it contains antibacterial, antioxidant, and insecticidal properties. In contrast, leaf extracts of *Moringa sp*. and *Mentha sp*. are well recognized for extending vase life. *Moringa olifera*, *Mentha piperita*, and *Calotropis procera* leaf extracts at 2 and 4% concentrations were employed in holding solutions to assess their effects on vase life, physiological and metabolic activities of gladiolus cut spikes. In contrast to *Moringa olifera* leaf extract (MOLE) and *Mentha piperita* leaf extract (MPLE), *Calotropis procera* leaf extract (CPLE) at 2% showed greatest vase life up to 14.50 days, open florets (64%), and RFW (40%). Dehestani-Ardakani et al. (2022) sought to assess the effects of salicylic acid (SA) and extracts from the leaves of *Salix* and *Mentha* (SE and ME) on the post-harvest quality and vase life status of cut carnation flowers. Vase solutions containing different concentrations of SA (50, 100, and 150 mg L^{-1}) and SE and ME (25, 50, and 100 mg L^{-1}) were applied to cut carnations. All SE, ME, and SA doses significantly extended the vase life and raised the antioxidant enzyme activity of peroxidase (POD), catalase (CAT), and proteins as well as the membrane stability index (MSI). A significant increase in vase life was seen upon exposure to 50 and 100 mg L^{-1} SA. The bacterial population in flowers treated with 150 mgL^{-1} SA vase solution was 83% lower than the control. When compared to the untreated control, the SA-treated flowers showed a substantial rise in protein, CAT, and POD activities. The effectiveness of essential oils on physical, physiological, and biochemical parameters during the vase life period of chrysanthemums was determined by Nirmala et al. (2023). Following pulsing with a 10% sucrose solution, 2.5% and 5% concentrations of artemisia, ocimum, geranium, and rosemary oils were utilized. Geranium oil 2.5% performed well across all parameters examined; this might be because cut chrysanthemum cv. Articqueen flower petals absorb more water and retain it better.

In order to extend the vase life of gladiolus, Thakur et al. (2023) investigated the antibacterial properties of lemon grass (LG) essential oil. The findings showed that treatment with a lower dose of 5 µL L^{-1} LG essential oil extended the gladiolus vase life by up to 11 days (d) in comparison to control (distilled water). The sample treated with 5 µL L^{-1} LG essential oil revealed intact vasculature, indicating reduced microbial obstruction at the stem end, as confirmed by microbial counts observed via Scanning Electron Microscope (SEM). According to biochemical examination, flowers treated with LG had greater levels of carotenoid content, total soluble sugars, and antioxidant enzyme activity, as well as decreased MDA buildup. Thakur et al. (2023) found that the lower dose of 5 µL L^{-1} LG oil in the vase solution increased the vase life of the gladiolus cut spike as well as the relative fresh flower weight and flower diameter. Thus, cut flowers' postharvest life may be increased using LG oil, an environmentally favorable substance. Jamja et al. (2024) investigated the efficacy of plant-based extracts as feasible, environmentally acceptable flower preservation solutions. The trial included three treatments of green tea extract (GTE) and cinnamon powder extract (CPE) at concentrations of 2, 2.5, and 3 g l^{-1}, as well as a control. At the end of the trial, treatment CPE (3 g l^{-1}) had the highest vase life (12.93 days), daily water absorption (16.57 ml^{-1} 2 day), total water uptake (86.91 ml), relative fresh weight (120.59%), MSI (79.44%), and the lowest CFU counts (5.12 log10 CFU ml^{-1}). GTE (3 g l^{-1}) was then added to all of the measured parameters. Green tea and cinnamon powder extracts were efficient treatments that greatly enhanced floral postharvest quality compared to control. Sage and rosemary essential oils (EOs) appear to be efficient eco-friendly floral preservatives due to their antibacterial and antioxidant content. A study by Moussa et al. (2024) looked at whether cutting gladiolus spikes and utilizing sage or rosemary essential oils as new preservative methods may improve their quality and extend their vase life. Gladiolus spikes were exposed to several concentrations of sage or rosemary essential oils in a vase solution (0, 50, 100, 150, and 200 mg L^{-1}). In comparison to the control, all concentrations of both EOs considerably boosted the gladiolus spikes' water intake, improved floret opening, and extended their vase life. Applying 150 or 100 mg L^{-1} of sage or rosemary essential oils, respectively, extended the vase life by 88.16 and 84.76% in comparison to the untreated spikes (El-Shawa et al. 2019).

5. CONCLUSION

In conclusion, increasing the vase life of cut flowers—particularly gladiolus, tuberose, carnations, gerbera and chrysanthemums—is essential to raising their market value. Plant-based substitutes including lemongrass essential oil, moringa leaf extract, and sage or rosemary essential oils provide promising environmentally benign alternatives to conventional flower preservatives, which frequently present environmental hazards. When paired with good post-harvest care, these natural preservatives may greatly extend the life of flowers while lessening their negative ecological effects. By increasing both flower freshness and environmental sustainability, further research into sustainable preservative solutions has the potential to completely transform the floral business.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

ACKNOWLEDGEMENT

I thankfully acknowledged the grant provided by the Council of Science and Technology, Uttar Pradesh, vide letter number CST/D-1417, dated October 20, 2023, for the project entitled “Improvement of Vase Life of Economically Important Cut Flowers Using Eco Friendly Chemicals and Functional Genomics Approaches for the Benefit of Farmers and Stakeholders of Western Uttar Pradesh” (Project ID-2776).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Ahmad, I., Rafiq, M. B., Dole, J. M., Abdullah, B., & Habib, K. (2017). Production and postharvest evaluation of selected exotic specialty annual cut flower species in Punjab, Pakistan. *HortTechnology*, *27*(6), 878-883.

Akhtar, G., Rajwana, I.A., Sajjad, Y., Shehzad, M.A., Amin, M., Razzaq, K., ... & Farooq, A. (2021). Do natural leaf extracts involve regulation at physiological and biochemical levels to extend vase life of gladiolus cut flowers?. *Scientia Horticulturae*, *282*, 110042.

Amin, O.A. (2017). Effect of some chemical treatments on keeping quality and vase life of cut chrysanthemum flowers. *Middle East J. Agric. Res,* 6(1), 208–220.

Darras, A. (2021). Overview of the dynamic role of specialty cut flowers in the international cut flower market. *Horticulturae*, 7: e7030051

Datta, S., Jana, D., Maity T.R., Samanta, A., Banerjee, R. (2016). *Piper betle* leaf extract affects the quorum sensing and hence virulence of Pseudomonas aeruginosa PAO1. *3 Biotech* 6:18. https://doi.org/10.1007/s13205-015-0348-8

De, L.C., Deb, P., Chhetri, G. et al. (2015). Pre- and post-harvest physiology of Cymbidium orchids. *International Journal of Horticulture*. 5(6):1– 5.

Dehestani-Ardakani, M., Gholamnezhad, J., Alizadeh, S., Meftahizadeh, H., &Ghorbanpour, M. (2022). Salicylic acid and herbal extracts prolong vase life and improve quality of carnation (*Dianthus caryophyllus* L.) flowers. *South African Journal of Botany*, *150*, 1192-1204.

El-Shawa, G. M., El-Saka, M. M., & Abd EL-Kafie, O. M. (2019). Evaluation of several ag+ sources and some essential oils for prolonging vase life of gerbera cut flowers cv. *Egyptian Journal of Agricultural Research*, *97*(2), 385-302.

Ezhilmathi, K., Singh, V.P., Arora, A., Sairam, R.K. (2007). Effect of 5-sulfusalicylic acid on antioxidant activity in relation to vase life of gladiolus cut flowers. *Plant Growth Regul*. 51, 99–108.

Glover, B.J., Martin, C. (1998). The role of petal cell shape and pigmentation in pollination success in *Antirrhinum majus*. *Heredity (Edinb)* 80, 778–784.

Hashemabadi, D., Kaviani, B., Shirinpour, A., & Yaghoobi, D. (2015). Response of cut carnation (*Dianthus caryophllus* L. cv. Tempo) to essential oils and antimicrobial compounds. *Int J Biosci,* 6:636–644

Hassan, F. A. S., Mazrou, R., Gaber, A., & Hassan, M. M. (2020). *Moringa* extract preserved the vase life of cut roses through maintaining water relations and enhancing antioxidant machinery. *Postharvest Biology and Technology*, *164*, 111156.

Hassan, F.A.S., & Fetouh, M.I. (2019). Does moringa leaf extract have preservative effect improving the longevity and postharvest quality of gladiolus cut spikes?. *Scientia Horticulturae*, *250*, 287-293.

Hassan, F.A.S.; Schmidt, G. (2004). Postharvest characteristics of cut carnations as the result of chemical treatments. *Acta Agron. Hung*., 52, 125–132.

Jamja, T., Tabing, R., Akhtar, S. F., & Boruah, P. (2024). Eco-friendly vase solution using green tea and cinnamon extracts for extending the vase life of black centered gerbera (*Gerbera jamesonii* L.) cv. Intense. *Journal of Eco-friendly Agriculture*, *19*(1), 49-54.

Kantharaj, Y., Madaiah, D., Naik, H., & Nadukeri, S. (2018). Significance of essential oils and herbal extracts on vase life of cut flowers: A review. *Journal of Pharmacognosy and Phytochemistry*, 7(3S), 252-256.

Kumar, M., Chaudhary, V., Yadav, M.K. et al. (2024a) RNAi: A Potent Biotechnological Tool for Improvement of Ornamental Crops. *Plant Mol Biol Rep*. https://doi.org/10.1007/s11105-024-01475-0

Kumar, M., Panwar, V., Chaudhary, V., & Kumar, R. (2024). Artificial miRNAs: A potential tool for genetic improvement of horticultural crops. *Scientia Horticulturae*, 331, 113160.

Kumar, M., V. Chaudhary, M. Kumar, U. Sirohi and M.K. Yadav (2021). Application of Conventional and Mutation Approaches in Genetic Improvement of Tuberose (*Polianthes tuberosa* L.): A review on Recent Development and Future Perspectives. *Int. J Agric Environ Biotech*., 14(3), 277-297.

Kumar, N., R.K. Dubey, R.L. Misra and S. Misra (2002). Pre-and Post-harvest factors influencing cut flower longevity. Floriculture research trend in India. Proceedings of the national symposium on Indian floriculture in the new millennium, Lal-Bagh, Bangalore, 25-27 February.

Kumar, R., Yadav, M. K., Kumar, M., Vaishali, Kumar, P., Gangwar, L. K., & Shankar, B. A. (2023). Effect of different concentrations of sodium nitroprusside (SNP) and salicylic acid (SA) on vase life of tuberose (*Polianthes tuberosa* L.) cv Prajwal. Environment and Ecology, 41 (1): 45—52

Kumar, R., Yadav, M. K., Shankar, B. A., Sharma, S., & Rani, R. (2022). Effect of different chemicals to enhance vase life of tuberose (*Polianthes tuberosa* L.) cut flowers. *International Journal of Agricultural and Statistical Sciences*, *18*(1), 995-1002.

Kumar, R., Yadav, M. K., Sharma, A. K., Vaishali, Kumar, M., Sirohi, U., Chauhan, C. (2024). *In-silico* characterization and expression profiling of cut flower vase life-related genes of Tuberose (*Polianthes tuberosa* L.). *Plant Science Today* (accepted). https://doi.org/10.14719/pst.4970

Ma, N., Ma, C., Liu, Y., Shahid, M. O., Wang, C., & Gao, J. (2018). Petal senescence: a hormone view. *Journal of Experimental Botany*, *69*(4), 719-732.

Macnish, A.J., Leonard, R.T., Nell, T.A. (2008). Treatment with chlorine dioxide extends the vase life of selected cut flowers. *Postharvest Biol. Technol*. 50, 197–207.

Mazrou, R.M.; Hassan, S.; Yang, M.; Hassan, F.A.S. (2022). Melatonin preserves the postharvest quality of cut roses through enhancing the antioxidant system. *Plants*, 11, 2713.

Moussa, M.M.; Mazrou, R.M.; Hassan, F.A.S. (2024). How Sage and Rosemary Essential Oils Regulate Postharvest Senescence and Extend the Vase Life of Cut Gladiolus Spikes. *Horticulturae*, 10, 638. https://doi.org/10.3390/horticulturae10060638

Nguyen, T.K.; Jung, Y.O. and Lim, J.H. (2020). Tools for cut flower for export: Is it a genuine challenge from growers to customers? *Flower Res. J.* 28, 241–249

Nirmala, A., Rao, A. M., Prasanth, P., Vijayalaxmi, M., Reddy, S. N., & Srinivasachary, D. Effect of essential Oils on Extension of Vase Life of Cut Chrysanthemum cv. Arcticqueen. *Biological Forum – An International Journal*, 15(8): 169-174.

Redman, P.B., Dole, J.M., Maness, N.O., Anderson, J.A. (2002). Postharvest Handling of nine specialty cut flower species. *Sci. Hort.* 92, 293–303.

Scariot, V., Paradiso, R., Rogers, H., & De Pascale, S. (2014). Ethylene control in cut flowers: Classical and innovative approaches. *Postharvest Biology and Technology*, *97*, 83-92.

Sharma, A. K., Yadav, M. K., Kumar, M., Sengar, R. S., Gangwar, L. K., & Kumar, R. (2024). Improvement in Vase Life of Gladiolus Cut Flowers Using Different Holding Solutions of Sodium Nitroprusside and of Salicylic Acid. *Journal of Advances in Biology & Biotechnology*, *27*(1), 211-224.

Sharma, S. and I. Sarkar, (2018). Influence of pulsing and holding solutions in vase-life of gladiolus cv. American beauty. *International Journal of Chemical Sciences*, 6(2): 2471-2474.

Singh, K., Sharma, R., & Sahare, H. (2022). Implications of synthetic chemicals and natural plant extracts in improving vase life of flowers. *Scientia Horticulturae*, 302, 111133.

Sirohi, U., M. Kumar, P. Kumar, M.K. Singh, N. Kumar, S. Prakash, P. Chand, R.K. Naresh, V.R. Sharma and V. Chaudhary (2017). Genetic diversity in single and double type of tuberose (Polianthes tuberosa L.) germplasm using randomly amplified polymorphic DNA (RAPD) markers. *Int. J.Curr. Microbiol. App. Sci*, 6(5), 1313- 1321.

Sirohi, U., M. Kumar, V.R. Sharma, S. Teotia, D. Singh, V. Chaudhary, Priya and M.K. Yadav (2022). CRISPR/Cas9 System. A Potential Tool for Genetic Improvement in Floricultural Crops. *Mol Biotechnol*., 25, 1-16. DOI: 10.1007/s12033-022-00523-y

Solgi, M.; Kafi, M.; Taghavi, T. S.; Naderi, R. (2009) Essential oils and silver nanoparticles (SNP) as novel agents to extend vase-life of gerbera (*Gerbera jamesonii* cv. "Dune") flowers. *Postharvest Biol. Technol*., 53, 155–158.

Thakur, M., Verma, V., Chandel, A., Kumar, R., Sharma, T., Kumar, A., ... & Bhargava, B. (2023). Lemon grass essential oil improves *Gladiolus grandifloras* postharvest life by modulating water relations, microbial growth, biochemical activity, and gene expression. *Scientific Reports*, *13*(1), 2630.

Tsegaw, T., Tilahun, S., & Humphries, G. (2011). Influence of pulsing biocides and preservative solution treatment on the vase life of cut rose (*Rosa hybrida* L.) varieties. *Ethiopian Journal of Applied Science and Technology*, *2*(2), 1-16.

Wahocho, N.A., Miano, T.F., Leghari, M.H. (2016). Propagation of gladiolus corms and cormels: a review. *Afr. J. Biotechnol*. 15, 1699–1710.

Younis, A.; Akhtar, M.S.; Riaz, A.; Zulfiqar, F.; Qasim, M.; Farooq, A.; Tariq, U.; Ahsan, M.; Bhatti, Z.M. (2018). Improved cut flower and corm production by exogenous moringa leaf extract application on gladiolus cultivars. *Acta Sci. Pol. Hortorum Cultus.*, 17, 25–38.

Zencirkiran, M. (2005). Effect of sucrose and silver thiosulphate pulsing on stem-base cracking and vase life in *Leucojum aestivum* L. Flowers. *J. Hortic. Sci. Biotechnol*., 80(3), 332–334.

Zencirkiran, M. (2010). Effect of 1-MCP (1-methyl cyclopropene) and STS (silver thiosulphate) on the vase life of cut freesia flowers. *Sci. Res. Essays*., *5(17)*, 2409–2412.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/127693