Review Article

Eco-Friendly Chemicals for Sustainable Post-Harvest Life of Flowers: A Comprehensive Review

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ABSTRACT

The article evaluates the key factors affecting cut flower vase life, focusing on pre- and post-harvest conditions, as well as environmental aspects. Given the commercial constraints imposed by their limited Vase-life, the study underlines the necessity of sustainable and environmentally friendly floral preservatives in increasing flower freshness. It underlines the increased interest in plant-based extracts and biodegradable alternatives as potential replacements for existing chemical preservatives. In addition to extending floral durability, these natural preservatives also lessen their ecological effect when used in combination with the best post-harvest practices. These sustainable alternatives are being studied more and more by researchers who want to prolong the life of cut flowers while reducing their negative effects on the environment. The potential of environmentally friendly preservatives to transform the floral business and advance both flower freshness and environmental sustainability is highlighted in this research.

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. Later, they begin to senescitate, dehydrate, and abscise their petals. Additionally, postharvest diseases like graymold disease, which is brought on by the necrotrophic fungus *Botrytis cinerea*, can affect cut flowers. 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. 20218). 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 color 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 colors 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 senescendo 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 color, 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 (Figure.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.

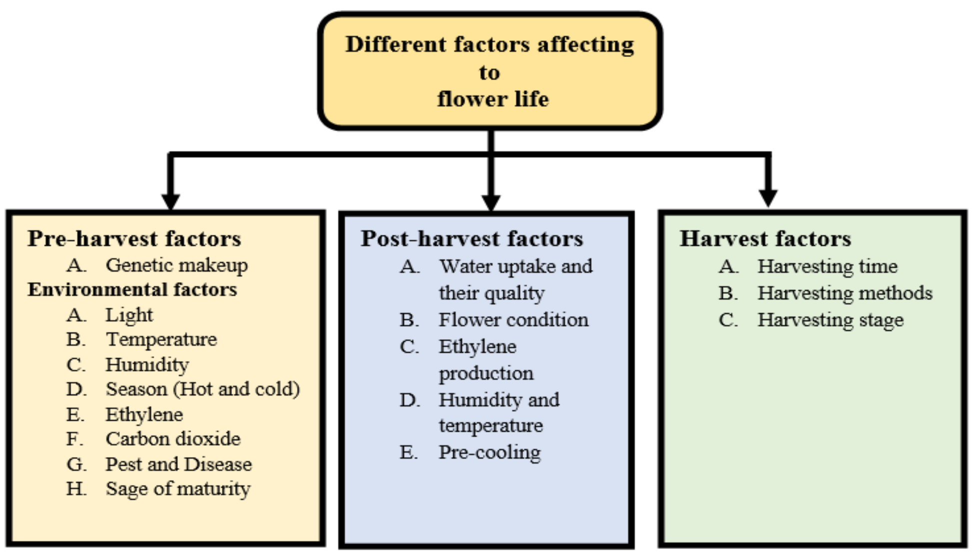

Figure 1: Factors affected the cut flower vase life

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. These include of temperature, ethylene, pH, water quality, water absorption, and harvesting time. 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 preservatives 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, environmentally friendly floral preservatives 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 research which are listed table 1.

Table 1. 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 acidand 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)

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. In conclusion, by maintaining water relations and strengthening the antioxidant machinery, MLE or MSE treatment increased the vase life of cut roses; the effect was stronger with MLE. As a result, the flower sector is advised to use MLE as a new preservative in the future.

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 the microbial count and seen by the 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) has 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.

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.

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