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COMPARATIVE EFFECT OF VARIOUS ORGANIC COMPOUNDS (CHITOSAN, THYMOL, AND EUGENOL) TO ASSESS THE DISPLAY LIFE OF CUT STEMS OF GLADIOLUS (*GLADIOLUS GRANDIFLORUS* L.)

Amna Zahid [1,*], Rabia Zahid [1], Ahsan Akram[1], Umar Bilal[1] and Muhammad Umair[2]

[1]Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan
[2]Postharvest Research and Training Centre (PRTC), Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan

*Corresponding author: amnazahid672@gmail.com

ABSTRACT

Gladiolus (*Gladiolus grandiflorus* L.) is a perennial flowering plant cultivated as a relishing spring cut flower in the plains of Pakistan. The cut stems of gladiolus remain metabolically active by utilizing the stored tissue substrate, but that is insufficient to keep them fresh not more than a few days. Keeping them fresh for a longer period is the topic of interest for both the growers and the florists. In this regard, an experiment was enacted to assess the comparative effect of three organic preservatives, namely chitosan, thymol, and eugenol, in extending the vase life of gladiolus. The observational units used in this experiment were at the same stage of maturity. Cut stems of cultivar "White Prosperity" were harvested from a private commercial flower farm, namely "Zarkhaiz Farm, Qasur. The treatment combinations comprising eighteen treatments in vase solution were kept at 20, 40, 60, 80, 100, and 120mg/L of three organic chemicals in the same concentration compared with the control (distilled water). Data was collected regarding various parameters, including vase life of spike, average life of flower, time to start wilting, petal browning, flower quality, relative fresh weight, dry weight % age, solution uptake, floret diameter, solution uptake of Gladiolus flower, and number of florets open. The experiment was executed according to a completely randomized design (CRD) under factorial arrangements with eighteen treatments and replicated thrice. The data was evaluated through Fisher's Analysis of variance technique, and treatment means were compared using Tukey's Test at 5% level of significance.

Keywords: *Gladiolus grandiflorus*, Organic Compounds, Cut Flower, Shelf Life

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1. INTRODUCTION

A massive increase in the production and trade of cut flowers during the 21st century has been significant increase in the production and trade of cut flowers has been recorded during the 21st century (Darras 2021). Interesting findings are also obtained from a country-by-country study of export data for cut flowers. The Netherlands continues to hold a sizable and historic portion of the worldwide export market (which includes reexports), although its proportion has decreased over the previous ten years, falling from 56% in 2011 to 48% in 2019 and 50% in 2020, while Ethiopia has established its foothold, and Kenya, Colombia, and Ecuador maintained their respective positions of second, third, and fourth in the global floriculture landscape (Malviya and Vala 2022). According to Future Market Insights (FMI), the global revenue from the Floriculture Industry is expected to rise to $ 43.2 billion with an annual growth rate of 7.0% (Anumala and Kumar, 2021). The growing demand for better and value-added floricultural products has encouraged farmers in other parts of the world, such as Ethiopia, Ecuador, Colombia, and Kenya, to capitalize on their naturally favorable climatic conditions for flower production and to grow and export flowers (Gabellini 2022). Over the past 40 years, the Netherlands has built a great flower culture industry, operating two huge flower auction markets "Flora Holland" and "Aalsmeer," operating five days (Azeez et al. 2007). More than a hundred countries used to send their produce on a daily basis to these auctions, which have a diverse online buying and selling system (Arora et al. 2006; Anderson 2023; Hashmi et al. 2024). The global flower trade reached 8.6 billion US$ in 2017 from 4.1 billion US$ in 2002 (Williamson et al. 2002). Similar to many other Asian countries, particularly in Pakistan, flowers are now cultivated on a larger scale as commercial crops, with more than 2,500 growers, 1,000 wholesalers, and 1,000 retailers directly involved in the flower business (Moussa et al., 2024). Rose, tuberose, gladiolus, and marigold were the only flowers grown in Pakistan in the past. However,

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many new flower crops have been cultivated at a commercial scale, including stock, delphinium, celosia, chrysanthemum, gypsophila, snapdragon, sunflower, etc. In Pakistan, cut flowers are commonly used in bouquets and various decorations, while loose flowers are used in garden displays, religious offerings, and to make hair adornments and bracelets for women (Ahmad et al. 2017; Qayyum et al. 2024; Nasir et al. 2025).

Gladiolus grandiflorus originated in South Africa. It belongs to the family Iridaceae, sub-family Ixioideae (Han 1992). Modern gladiolus is believed to have been bred from six native species, and currently, its genus possesses 225 species (Abdul 2016). In 2006, almost 19,900 stems of gladiolus were imported to the European floriculture market, apart from the Netherlands, at 0.52 US$ per stem, and 82,760 cut gladiolus stems were produced in Japan for 0.45 US$ (Alavi et al. 2015). Many European countries like the Netherlands earn more profits from the South African native flowers, i.e., gladiolus, than the country earns from its gold (Faust 2021). It is critical to assess cultivars with desirable traits that are adaptable to certain climatic conditions in order to increase their economic output (Kendirli and Cakmark 2007). Gladiolus, in addition to its intangible aesthetic value, is contributing to Pakistan's economy by earning and stabilizing important foreign exchange (Cantor and Tolety 2011). It is cultivated in gardens as a flower bed and is used in floral arrangements for interior decoration as well as to make high-quality bouquets (Clarke 1997). It is a winter flower, but it may be cultivated in the summer season in hilly areas of Pakistan, like Rawalakot, because the climatic circumstances are more conducive for its cultivation in summer, and it can be produced as an off-season crop with a higher possibility of yield (Aziz et al. 2021). Gladiolus is the most important flowering crop grown commercially for the cut flower industry in Pakistan (Riaz et al. 2007). Therefore, appropriate consideration is required throughout the production channel, from sowing to post-harvest management, to gain a better place in the global market (Khan et al. 2015).

Ethylene production and microbial plugging at the cut end of stems become the cause of tepal senescence and eventually, the shorter display life of cut flowers (Kesli and Adak 2012). Developing negative water balance, dehydration, and uneven carbohydrate distribution are some of the other factors responsible for the earlier death of flowers. Specialty cut flowers have shorter vase life, i.e., they are highly perishable as well as intricate plant organs that must be handled and maintained carefully to retain their freshness and display quality. Gladiolus has a shorter vase life owing to bacterial vascular blockage (Sudhakar and Kumar 2012). Bacterial growth and degradation products induce stem obstruction in cut flowers. The cut stems require a continuous additional energy source to keep the tissues alive and an antibacterial solution to stop the growth and attack of microorganisms (Hashemi et al. 2014). Organic compounds provide both of these to the cut stems; that is why they are recommended by scientists to be efficiently used in prolonging the display life of cut flowers (Kim et al. 2002). Organic compounds such as thymol, eugenol, chitosan, etc. contain high levels of essential oils, which are an excellent source of controlling microbial growth (Shokalu et al. 2018). Chitosan is the most common polysaccharide obtained from the exoskeleton of several crustaceans, especially from shellfish (lobster, crab, shrimp, etc.), also present in the cell walls of various algae and fungi, and in the cuticle of insects. It is a nontoxic, biocompatible, renewable, biodegradable material and known for its antimicrobial, antifungal, and broad-spectrum antioxidant activity. Thymol, which is present in the essential oil of *Thymus pannonicus*, contains outstanding in vitro antibacterial properties against imperative pathogens such as yeasts and microorganisms (El-Sayed et al. 2025). *Thymus vulgaris* (containing a mixture of terpenoids, thymol, and isomeric carvacrol) possesses excellent antibacterial and antioxidant impacts (Svircev et al. 2007). Eugenol ($C10H12O2$, 4-Allyl-2-methoxyphenol), commonly known as “clove oil,” is a yellowish, glossy, spicy-scented liquid found in several herbaceous plants belonging to Myrtaceae and Lauraceae, usually extracted from Clove (*Syzygium aromaticum* L.). *S. aromaticum’s* buds and leaves are a good source of this propene, cultivated at a commercial scale in Indonesia, Sri Lanka, Malaysia, India, Tanzania, and Madagascar (Han 1992). It is one of the most important essential oils used in medicines as well as the floricultural industry for its preservative properties (Konsam and Sahu 2023). It has special antimicrobial, antifungal, and antiseptic effects (Salmasi 2020). That is why it is used as a floral preservative solution to extend the display life of cut flowers. Eugenol prevents the growth of yeasts and molds in the vase water, thus inhibiting stem blockage of the flower. It is also helpful in controlling microbial growth in vase solution, which in turn inhibits the production of ethylene and sustains the quality of cut flowers (Hashemi et al. 2014).

Given the commercial significance of *Gladiolus grandiflorus* L. cv. “White Prosperity” in the Pakistani floriculture market and its inherently limited postharvest longevity, the present study was designed to evaluate the effect of three organic compounds (chitosan, thymol, and eugenol) when applied through vase solutions. The primary objective was to assess the efficacy of these compounds in enhancing the display life of cut gladiolus stems and to determine their optimal concentrations and compatibility as floral preservatives.

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2. MATERIALS AND METHODS

2.1. Plant Material and Organic Chemicals

Cut stems of gladiolus were harvested from Zarkhaiz Farms (Pvt.) Ltd., located in Lahore, Pakistan, and were shifted to the laboratory under a cool chain system. The cultivar of white prosperity of *Gladiolus grandiflorus* was purchased. All observational units were at the same stage of maturity (when the lowermost floret showed the color of the petal). All the leaves were removed, the stems were sorted out, and trimmed at a uniform length of 2.5ft.

All three organic compounds used in the research were purchased from Tufail Chemicals, located in Karkhana Bazar, Faisalabad. Vase solutions of three different organic compounds, i.e., chitosan, thymol, and eugenol, were prepared at concentrations of 20, 40, 60, 80, 100, and 120mg/L, with distilled water serving as the control treatment. The experiment consisted of 18 treatments with three replications.

To prepare the working vase solutions of 1.5L for each concentration, the required amounts of chitosan, thymol, and eugenol were directly weighed and dissolved to achieve the desired concentrations. Accordingly, 30, 60, 90, 120mg, 150mg, and 180mg of each compound were used to obtain 20, 40, 60, 80, 100, and 120mg/L solutions, respectively (Table 1).

Table 1: Amount of compound required to prepare 1.5L vase solution at different concentrations

Treatment concentration (mg/L)	Amount of compound (mg) for 1.5 L stock solution
20	30
40	60
60	90
80	120
100	150
120	180

2.2. Data Collection

Three healthy and vigorous cut stems of gladiolas were selected for each replication; there were 18 treatments and three replications, i.e., 144 total cut stems. The stems were sorted out to a uniform length of 2.5ft. and kept in vase solutions all on the same day. Each treatment was labelled separately, and data were collected for the accompanying parameters.

2.2.1. Vase Life (Days): The aesthetic attractiveness of the stems was assessed daily. The vase life was considered to be over if half of the florets were wilted, stems were broken, or the aesthetic quality of the entire stem did not match commercial with the requirements, and the average vase life was calculated by counting the number of days and hours when they were still fresh (Ahmad et al., 2017). The stems were sorted out and standardized to a uniform standard in each experimental unit. Stem length was maintained at a uniform length of 2.5ft.

2.2.2. Average Life of Flower (Hours): The Average life of a flower will be calculated by counting the number of hours starting from the opening of the bud till its stage when it loses its freshness. It will be noted from two spikes in replication, and then their average will be computed.

2.2.3. Relative Fresh Weight (% of Initial FW): Required number of cut stems of gladiolus were selected arbitrarily, reaped at a stage when the “bottom floret starts showing color”, brought to the Postharvest Floriculture Laboratory, Institute of Horticultural Sciences, University of Agriculture, Faisalabad. One stem/replication was weighed on an electric weight balance to take the relative fresh weight on day 5 of vase life, and the average was calculated:

$$RFW\ (\%\ of\ initial\ FW) = (FW5/FW0) \times 100$$

Where FW0 = weight of stems on day 0, FW5 is the weight of stems at day 5 of vase life (Ahmad et al. 2017).

2.2.4. Flower Quality (1-9): Flower quality will be rated from 1-9 by three different judges (postgraduate floriculture students) by following the method given by Dest and Guillard (1987) and Cooper and Spokas (1991), and the average number will be noted down. According to this method, flower quality will be rated in numbers using the following scale:
1 = Poor Quality
5 = Medium Quality 9 = Good Quality
Flower quality will be judged when 50 % florets are opened on the spikes.

2.2.5. Dry Spike Weight (%): Dry weight %age was calculated by using following formula:
Dry weight 5 age = (DW/FW) × 100

The dry weight of the same flower whose fresh weight was measured earlier on day 0 from each replication and averaged. For estimation of dry weight, stems will be sun-dried for one day, then packed in butter paper bags and kept in an oven at 80˚C for 48 hours to record the dry weight at the end of vase life. Dry weight %age of one spike will be measured from each replication, and the average will be worked out.

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2.2.6. Solution Uptake (mL): Weights of vases (g) without stems were recorded to quantify the amount of water absorbed by the stems over the first five days of vase life. The following formula was used to determine the amount of water taken in:
Solution uptake (mL) = ($S_0 – S_5$)
Ten stems per treatment were tested for water/solution absorption; the average was determined and reported in mL equivalents (He et al. 2006; Ahmad et al. 2017).

2.2.7. Water Loss of Gladiolus Flower: Water loss rate is calculated as:
Water loss rate ($g·h^{−1}$) = water uptake rate + FW change.
The latter was calculated as: FW change ($g·h^{−1}$) = (FW*t-1* – FW*t*) × 2; where FW*t* is the weight of cut flower stem (g) at *t* = min 30, 60, 90, etc.; and FW*t-1* is the weight of the cut stem (g) at the previous 30 min.

2.3. Statistical Analysis
Factual examination of information was completed through factorial arrangements under a completely randomized design (CRD) with eighteen treatments, excluding the control one and three replications. The research data was evaluated through Fisher's Analysis of variance technique, and treatment means will be collated through Tukey's Test at 5% level of significance (Steel et al. 1997).

3. RESULTS

3.1. Vase Life of Cut Flower (Days)
Data depicted highly significant differences (P<0.01) among treatments, as all the treatments had longer vase life than the control (Fig. 1). Among treatments, T18 (Eugenol 120mg/L) performed best and resulted in the highest vase life (14.33 days).

3.2. Time to Start Wilting (Days)
All treatments significantly (P < 0.01) affected the time to start wilting of gladiolus flowers, with maximum solution uptake at 120 mg/L eugenol, followed by 100 mg/L, which was statistically similar, and then 80 mg/L. Other eugenol, chitosan, and thymol levels performed fairly well, while the control (distilled water) gave the lowest values (Fig. 1).

3.3. Flower Quality (1-9)
Data depicted highly significant differences (P<0.01) among treatments for the flower quality of gladiolas. Results showed that thymol application enhanced the flower quality more than chitosan and eugenol applications. Among all the treatments, T11, T17, and T18 (100 and 120mg/L of thymol, eugenol) gave the highest flower quality. While the minimum flower quality was observed in the control (distilled water) application (Fig. 2a and Fig. 2b).

3.4. Relative Fresh Weight (% of Initial FW)
Among the different doses of chitosan, thymol, and eugenol, the maximum relative fresh weight (80.01%) was recorded when thymol at 60mg/L was applied (T9), followed by the results obtained when thymol at 20mg/L (T7) was foliarly applied. However, control treatments, distilled water applied, gave minimum values for relative fresh weight (Fig. 3).

3.5. Solution Uptake (mL)
All the treatments markedly (P<0.01) affected the solution uptake of gladiolas flowers. The maximum solution intake was observed where eugenol was applied at a dose level of 120mg/L (T18), whereas statistically similar results were recorded where 100mgL^{-1} of eugenol (T17) was applied, followed by 80mg/L eugenol (T16) application. However, other levels of eugenol, chitosan, and thymol gave fairly good results (Fig. 3).

3.6. Average Life of Flowers (Hours)
The analyzed results showed that all the treatments markedly (P<0.01) affected the average life of the gladiola flower. Among different doses of chitosan, thymol, and eugenol, the maximum average life of the gladiolas flower (218h) was recorded where eugenol 120mg/L was applied (T18), followed by the results recorded where eugenol 100mg/L and thymol 120mg/L (T17 and T_{12}) were applied (Fig. 4a and Fig. 4b).

3.7. Dry Spike Weight (%)
All the dried spikes from different treatments increase the dry spike weight compared to the control. However,

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the maximum dry spike weight was observed where eugenol was applied at a dose level of 120mg/L (T18), whereas the dry spikes in the control treatments had the lowest weight.

3.8. Water Loss of Gladiolas Flower (g h^{-1})

Analyzed results showed that all the treatments significantly (P<0.01) affected the water loss of gladiolas flowers. Among different doses of chitosan, thymol, and eugenol, maximum water loss (80.01) was recorded where thymol 60mg/L was applied (T9), followed by the results recorded where thymol 20mg/L (T7) was foliar applied. The control treatments, distilled water applied, gave minimum values for water loss.

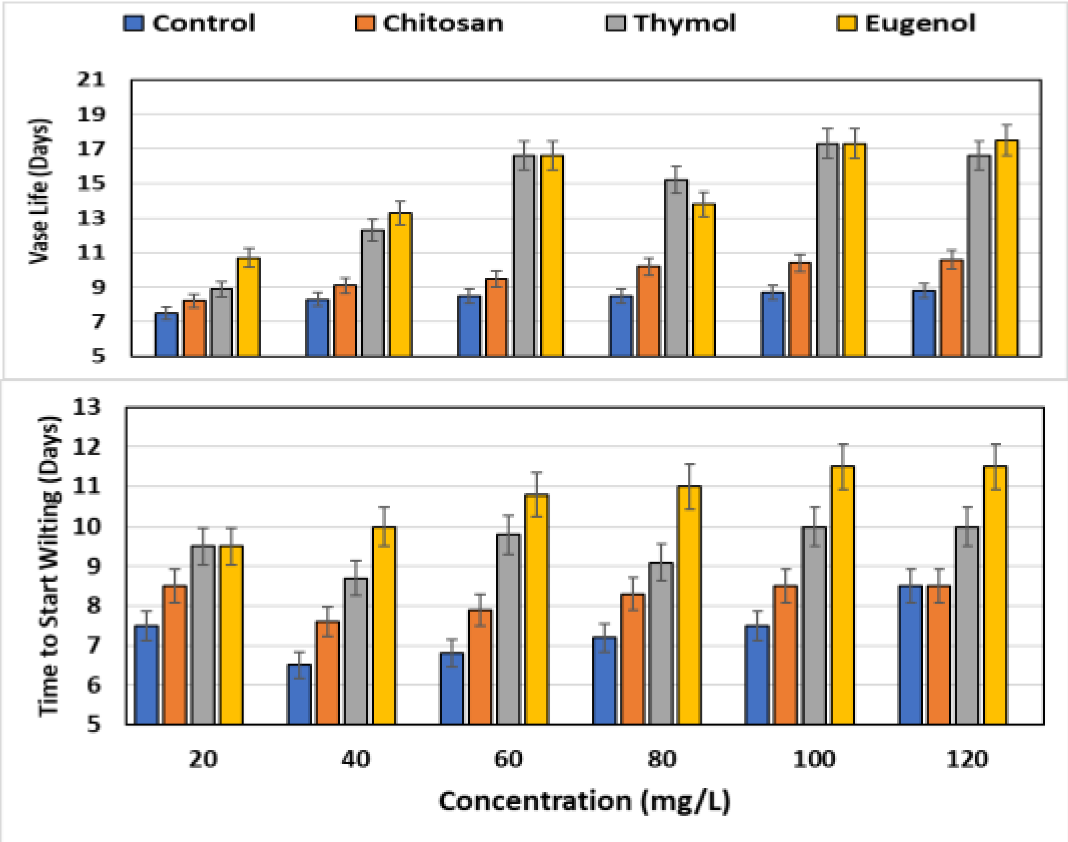

Fig. 1: Effect of concentration (mg/L) of chitosan, thymol, and eugenol on vase life and time to start wilting of *Gladiolus grandifloras*.

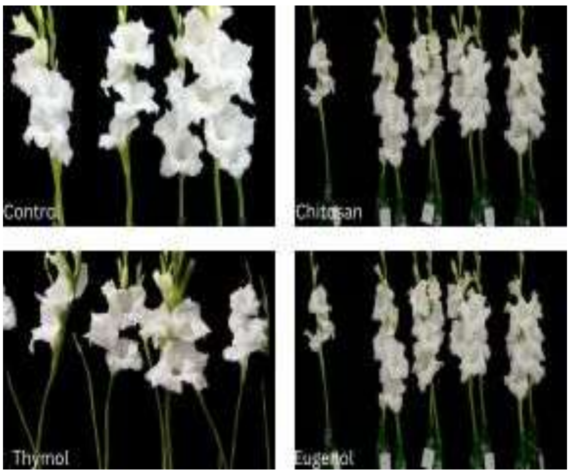

Fig. 2a: *Gladiolus grandiflorus* L. Cut Stems at day 5th of Vase life.

Fig. 2b: *Gladiolus grandiflorus* L. Cut Stems at day 8th of Vase life.

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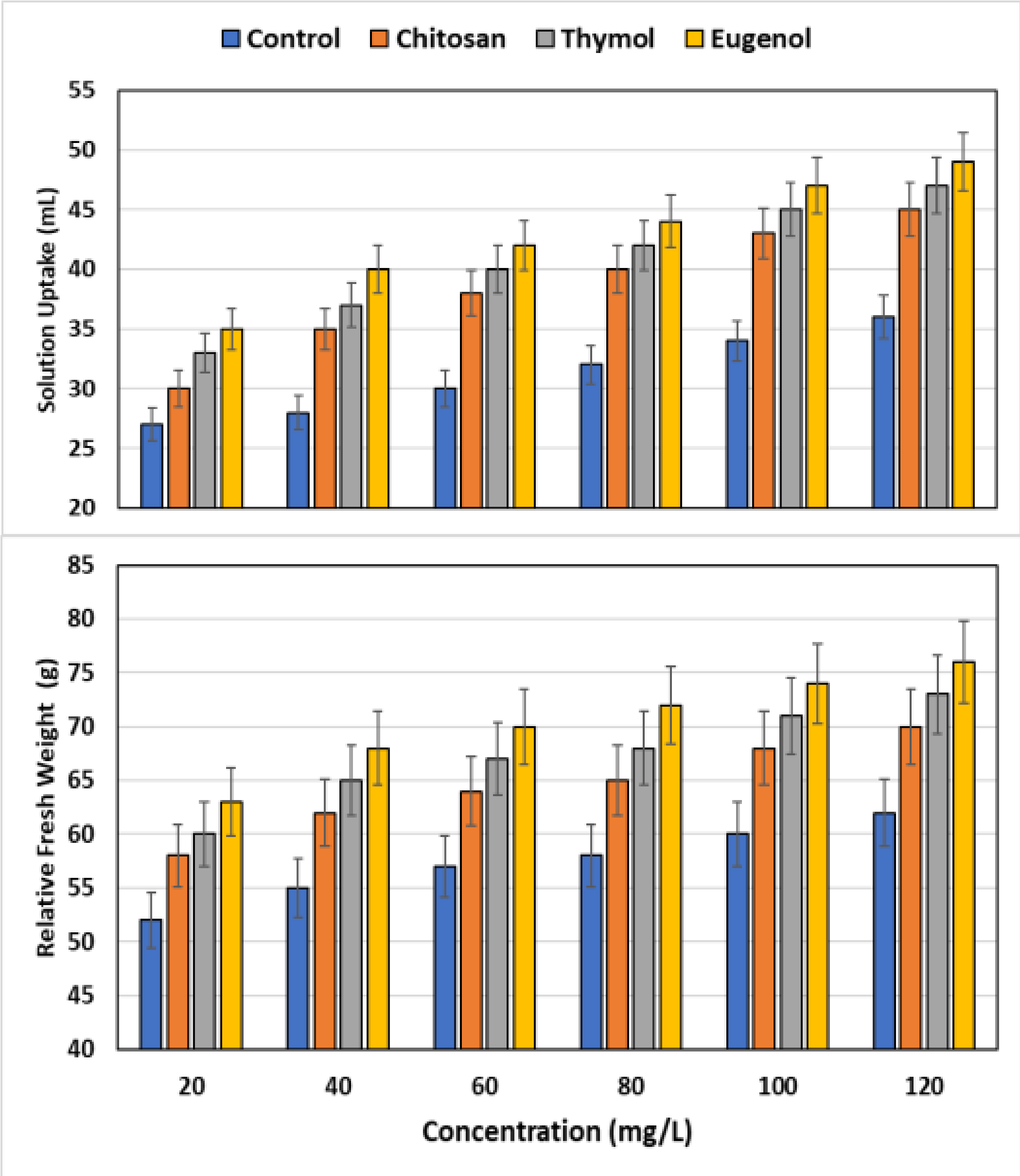

Fig. 3: Effect of concentration (mg/L) of chitosan, thymol, and eugenol on solution uptake and relative fresh weight of *Gladiolus grandifloras*.

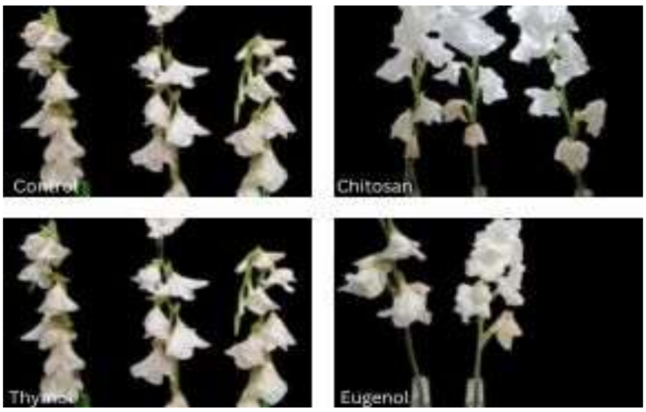

Fig. 4a: *Gladiolus grandiflorus* L. Cut Stems at day 8th of Vase life.

Fig. 4b: *Gladiolus grandiflorus* L. Cut Stems at the 8th day of senescence

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4. DISCUSSION

Flowers remain alive after being harvested, producing carbohydrate depletion, increased temperature and respiration rates, fast microbial assault, water stress, and increased ethylene buildup. All of these processes cause the blooms to deteriorate, reducing the fresh produce's shelf life. Post-harvest handling technologies are required. Due to variances in their genetic make-up, the post-harvest lifetime of flower species and cultivars varies greatly. Some flowers, like lilies, have a shorter vase life than roses and gerberas, whereas Anthurium and orchids have a longer vase life than roses and dianthus (Kaya et al. 2023). Gladiolus, on the other hand, has a shorter vase life as a result of bacterial occlusion (Verlinden 2004). Hydro cooling or refrigeration can be used to remove surplus field heat. The time between harvest and pre-cooling should be kept to a minimum (Hemanth Kumar et al. 2025).

It lowers the rate of respiration. Pre-cooling temperatures for roses are 1–3°C, chrysanthemums are 0.5–4°C, carnations are 1°C, and gladiolus are 4°C. Water acidification and the addition of a wetting agent and flower food to the holding solution significantly increase cut flower water absorption (Gilbert 2006). Gladiolus vase life is reduced when the concentration of salts in water surpasses 700ppm, while 200ppm is hazardous to chrysanthemums and carnations (Shabanian et al. 2018). Consumers, retailers, and producers all benefit from longer bloom life. Ethylene, a gaseous plant hormone, plays a role in flower life. Practically, microbial growth blocking the floral stem and inhibiting water intake reduces vase life. The ethylene biosynthesis process and the signaling pathways that induce senescence have been extensively studied (Manzoor et al. 2024; Victoria 2012; Yu et al. 2024). The ethylene production genes (ACC synthase and ACC oxidase) have been effectively suppressed, extending the vase life of carnations as well as the shelf-life of various fruits such as tomato, melon, and banana. The composition of the ambient environment has an impact on the lifespan and quality of cut flowers. On cut flowers, ethylene had the most negative impacts. Ethylene is first generated in the gynoecium in carnations (Victoria 2012). Chemicals applied to water to extend the life of flowers are known as floral preservatives. There are several organic, environment-friendly compounds known to have a great impact on extending the vase life of cut flowers (Yu et al. 2024). One of them is chitosan. The deacetylation of chitin produces chitosan [a copolymer of (1–4)-2-amino-2-deoxy-D-glucose and N-acetyl-D-glucosamine in various ratios]. It is a nontoxic, biocompatible, renewable, and biodegradable substance with antibacterial, antifungal, and broad-spectrum antioxidant properties that are dependent on the degree of deacetylation (Thakur et al. 2023). Chitosan inhibits or initiates plant–pathogen interactions, limits pathogen development, and triggers defensive responses. The effects of chitosan administration during plant growth on flower postharvest have been studied in several research studies; however, the consequences of its usage in preservative solutions remain unknown. The vase life of Lilium hybrid 'Siberia' flowers was increased using a vase solution comprising colloidal silver nanoparticles, hydrogen peroxide, and chitosan.

A floral preservative is not usually added or used alone. It is mixed with some acid, alkalis, or other solutions to dissolve them appropriately. For example, glacial acetic acid is used to dissolve chitosan. In this regard, the constituents of floral preservatives are also essential in maintaining the vase life of cut flowers. In the same way, microbial development is inhibited by acidic water with a pH of 3.0–3.5 (Van Doorn 1995). Sugar serves as an extra food source while also assisting with water balance. Because sugar encourages microbial development, it is frequently mixed with a biocide before usage. Glucose (reducing sugar) was shown to be the most efficient in increasing vase life, followed by fructose (Kuiper 1995). Essential oils (EOs) are safe and ecologically beneficial organic natural compounds. Because EOs include significant quantities of phenolic chemicals such as carvacrol, thymol, and eugenol, they have excellent antibacterial activity against certain infections (Chamani et al. 2005). Thymol, thyme oil, and zataria oil are used to combat plant diseases, especially on fruit (Svircev et al. 2007). Because of their antibacterial and antioxidant qualities, essential oils derived from the species listed above have been utilized in the food industry as flavoring and preservation agents since ancient times. Several types of Thymus, Ocimum, and Origanum are still used to season meats, salads and soups (Sudarshan 1992). Furthermore, during the last several years, the food industry has increased its use of these plants, their essential oils, and extracts in order to preserve food safety and reduce salt content, with the ultimate goal of lowering the prevalence of hypertension (Amnuaykan 2023). The European Commission has approved thymol and other components found in essential oils (such as carvacrol, carvone, cinnamaldehyde, citral, p-cymene, eugenol, limonene, and menthol) for use as safe-to-eat flavorings in food (Solgi 2018).

When a cut flower loses more water than it absorbs, it experiences a water deficit, leading to wilting. One of the primary reasons for this wilting is the flower's inability to uptake water, often due to the growth of microorganisms in the cambial tissues of the stem. This observation aligns with findings from previous studies, which reported that the addition of thymol (100mg/L) and carvacrol (50 and 100mg/L) to preservative solutions significantly extended the vase life of gerbera flowers compared to untreated controls. These results suggest that essential oils may enhance the water balance in cut flowers by preventing microbial blockage of stem vessels, thereby improving both longevity and visual quality. Essential oils, comprising mainly thymol (65%), carvacrol (5–10%), and eugenol (5–10%), are particularly valuable for their antibacterial and antioxidant properties. Reactive

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oxygen species (ROS) are known to damage cellular membranes. Therefore, a decrease in membrane stability is often associated with increased ROS activity and a concurrent decline in antioxidant enzyme function. The use of natural compounds in certain preservative formulations has been shown to enhance dry weight, vase life, and overall quality of cut flowers. This improvement is attributed to the protective effect of these compounds on cellular structures, which safeguards them from oxidative stress by enhancing the antioxidant capacity of the preservation medium. Consequently, membrane integrity, commonly targeted by ROS, remains protected. In this context, the antioxidant properties of essential oil constituents such as menthol, thymol, and eugenol likely contributed to maintaining membrane stability in our study. Our results demonstrated that all treatments significantly extended the vase life of cut flowers compared to the control. Among the tested treatments, eugenol at 120mg/L proved most effective, resulting in the longest vase life. Similarly, the highest relative fresh weight was recorded with the application of thymol at 60mg/L. Furthermore, when comparing treatment means of chitosan, thymol, and eugenol, the greatest solution uptake was observed with eugenol at 120mg/L. However, other concentrations of eugenol, as well as the treatments with chitosan and thymol, also produced reasonably good results

5. CONCLUSION

The findings of this study clearly indicate that the application of organic compounds, i.e., chitosan, thymol, and eugenol, positively influenced the vase life and postharvest quality of cut Gladiolus 'White Prosperity' spikes. The treatments significantly enhanced parameters such as vase life, average flower life, flower quality, relative fresh weight, dry weight percentage, solution uptake, time to wilting, petal browning, solution pH stability, floret diameter, and the number of florets opened. Notably, all tested treatments extended vase life compared to the control, with increasing concentrations of the applied substances further improving the results. Among these, eugenol at 120mg/L proved to be the most effective, resulting in the maximum vase life (14.33 days), followed by the applications of 100mg/L (14.3 days) and 80mg/L (13.8 days) eugenol. These results suggest that eugenol's known antimicrobial and antioxidant properties may have played a crucial role in maintaining water uptake and delaying senescence. In contrast, the control treatment with distilled water recorded the shortest vase life, highlighting the potential of these natural compounds in extending the postharvest longevity of cut flowers

DECLARATIONS

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Conflict of Interest: The Authors declare no conflict of interest.

Data Availability: All the data collected about this study are available within the article.

Ethics Statement: This study was conducted in accordance with all relevant ethical standards and approved guidelines.

Authors' Contribution: AZ and RZ wrote the initial draft of the manuscript. AA and UB made all necessary corrections and carried out final editing of the manuscript. AZ proofread the manuscript. All authors have reviewed and approved the final version of the manuscript for publication.

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