

## POSTHARVEST AND VASE LIFE ANALYSIS OF GLADIOLUS AND AMARYLLIS FLOWERS USING EXTRACTS OF GINGER AND CITRUS

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### Abstract

Gladiolus and Amaryllis are prominent flowering plants in Pakistan, grown primarily for their aesthetic appeal. However, due to the lack of proper postharvest management techniques, farmers and traders face significant losses. The study examined the influence of 2.5 & 5% of foliar application of ginger and citrus extracts on vase life and postharvest performance of Gladiolus and Amaryllis flowers. Different concentrations of the extracts were applied, and the effects on vase life, water uptake, floral head diameter and protein content etc., were measured. GE 5% (50ml/L) was found to increase the performance of cut flowers, which further increased the longevity of all Gladiolus and Amaryllis cultivars tested up to eight days and the longest vase life by 20.98 and 17.97 days, respectively. The maximum change in fresh weight (91.7 g), the increase in water uptake (27.33 and 25.97ml), flower head diameter (124.27 and 136.32 mm), dry weight of petal (1.13 and 1.29 g), total soluble solids (5.88 & 6.97 °Bx), highest protein content (66.33 and 65.02 mg g<sup>-1</sup>). The activities of total phenolic compound (TPC) 2.39 and 2.52 mg 100g<sup>-1</sup>, superoxide dismutase (SOD) (3.54 and 3.38 U g<sup>-1</sup>), catalase (CAT) (2.18 and 2.03 μ mol H<sub>2</sub>O<sub>2</sub>), and peroxidase (POD) (1.71 and 1.67 μ mol H<sub>2</sub>O<sub>2</sub>), also showed an increase. These results suggest that the use of 5% ginger extract can significantly improve the postharvest management of gladiolus and amaryllis in Pakistan, providing growers and retailers with a viable solution to their current challenges.

**Key words:** Ginger extracts; Citrus extracts; Vase life; Postharvest performance; Gladiolus and Amaryllis.

### Introduction

Gladiolus and Amaryllis are two ornamental plants. Gladiolus Grandiflora belongs to the family *Iridaceae*. It is indigenous to tropical and southern Africa. It is a flower that blooms during the winter and is grown for commercial cut flowers both abroad and in Pakistan. While Amaryllis belongs to the *Amaryllidaceae* family, which is widely distributed across the world's tropical and subtropical regions. Both have high botanical and horticultural values due to their uses in decoration and long-lasting life for décor purposes. These are an important ornamental plants use for ornamental purposes this is why horticulture interesting communities prefer to plant these. Gladiolus and Amaryllis floret spikes often only endure 6-7 days, which is not enough time for exporting the plant after harvesting to distant markets. For cut flowers to be sold, they must be able to resist the processes of harvest, packaging, and distribution while maintaining a level of quality that would satisfy the buyer.

Microorganisms, particularly fungi and bacteria that thrive in preservative solutions have a significant negative impact on the longevity of cut flowers. These microorganisms and their chemical byproducts block the stem extremities and reduce water absorption, thereby shortening the lifespan of flowers (Dineshbabu *et al.*, 2002). Including various compounds such as Nano-silver, silver thiosulfate, silver nitrate, hydrogen gas and calcium has increased the shelf life of cut flowers (Bai *et al.*, 2009;

Alimoradi *et al.*, 2013; Ahmad *et al.*, 2016). However, the high cost of these chemicals and the realization of their negative influence on human health and environment have shifted the focus of researchers towards eco-friendly agents. Due to its high phytotoxicity potential and detrimental heavy metal environmental contamination, silver can contaminate the environment (Shanan *et al.*, 2010; Damunupola *et al.*, 2008).

Researchers are looking at natural and environmentally safe preservative options for cut flowers because the majority of these chemicals have dangerous impacts on human health. Presently, several authors report that non-chemical alternatives such as essential oils and plant extracts are used to extend the vase life of many cut flowers (Bidarigh, 2015; Bazaz *et al.*, 15; Hashemabadi *et al.*, 2013). Due to the antimicrobial activities of their high levels of terpene and phenolic compounds, these environmentally safe natural organic compounds are used for post-harvest pathogen control (Basiri *et al.*, 2011; Braga *et al.*, 2008). Even though, in some cases, organic products are more expensive than synthetic or chemical alternatives, they are available for purchase in order to avoid toxic chemicals. In addition, there is a demand for novel floral preservatives that are natural and safe, as cut flowers are used in daily life in some way. We can therefore reduce our use of chemical preservatives. Moringa (*Moringa olifera*) extract in gladiolus, roses (Hassan *et al.*, 2020) guava (*Psidium guajava*), and *Andrographis paniculata* extract in mokara

(Rahman *et al.*, 2019), savory (*Satureja hortensis*) leaf extract in alstroemeria (Mohammadi and Jadid, 2019) and mentha (*Mentha procera*) extract in roses, hydrogen gas for cut rose 'Movie star', 8-HQS for hydrangea cut flower (Kazaz *et al.*, 2020) have been widely used in enhancing the shelf life and cut flowers quality (Salmi *et al.*, 2018).

Citric acid (CA) is an organic acid derived from citrus fruits that serves as a source of carbon and energy for cells, as well as a component of the respiratory cycle and other biosynthetic processes (Darandeh & Hadavi, 2012; Da Silva, 2003). CA decreases the population of microorganisms in vessel solution and increases the water conductivity of cut flowers in xylem (Kazaz *et al.*, 2017). Similarly, Ginger (*Zingiber officinale* Roscoe), a member of the Zingiberaceae family, is one of the most significant and extensively used spices in the world. Bellik (2014) that the essential oil extracted from dehydrated ginger rhizomes is rich in bioactive compounds and has antioxidative free radical scavenging properties. In addition, ginger essential oil has antibacterial and antifungal properties (Mesomo *et al.*, 2013; López *et al.*, 2017). Therefore, present research was conducted to determine the effect of citric and ginger extracts on the postharvest quality and vase life of *Gladiolus* and *Amaryllis* cut flowers when used in pulsing and holding preservative solutions.

## Materials and Method

**Experimental site:** The research was conducted at the Horticulture Research Area, University of Haripur Coordinates: 33°58'41.4"N 72°54'45.7"E Department of Horticulture, University of Haripur, Khyber Pakhtunkhwa, Pakistan, in 2021-2022. *Gladiolus* and *Amaryllis* corms were acclimatized, and postharvest tests were performed to evaluate plant extracts on quality and vase life. Spikes, harvested in the morning with lower florets starting to color, were trimmed to 70 cm with an average of 12 flowers per spike.

**Treatments:** The study used 200 ml of holding solution in pristine glass bottles, with a control of pure distilled water. Conditions were controlled at 60% relative humidity, 12°C ± 2°C, and 733 lux light intensity. Treatments included T0: distilled water, T1: 25 ml/L ginger extract (2.5%), T2: 50 ml/L ginger extract (5%), T3: 25 ml/L lemon extract (2.5%), and T4: 50 ml/L lemon extract (5%).

**Preparation of ginger extract:** Ginger extract was made from fresh rhizomes from Haripur, Khyber Pakhtunkhwa, Pakistan. After washing and drying at 40°C for 48 hours, the rhizomes were ground and stored at -15°C. Soxhlet extraction with 85% ethanol was followed by concentration and drying. The extract was stored at 5°C, and 2.5% and 5% solutions were prepared with distilled water for use.

**Preparation of citrus extract:** Lemon juice was manually squeezed and homogenized in methanol and water. Solutions were mixed thoroughly and diluted with distilled water to prepare 2.5% and 5% concentrations for foliar application and vase solution.

**Trait measurement and data analysis:** Vase life and water uptake was measured by method given by (He *et al.*, 2006). Relative fresh weight was by the formula:

$$\text{Relative fresh weight (\%)} = \frac{\text{Final weight}}{\text{Initial weight}} \times 100$$

Petal ion leakage was measured with an EC meter (Ahmad, 2009) using: Ion Leakage (%) =  $EC_2 / EC_1 \times 100$ . Total soluble solids (Brix) were assessed with a digital refractometer (Bayleyegn *et al.*, 2012). pH was measured with a H meter (MW802). Total phenolic compounds were quantified by the Folin-Ciocalteu method (Liang *et al.*, 2018). Superoxide dismutase, catalase, and peroxidase activities were measured as per Štajner & Popović (2009) and Liu *et al.*, (2009). Protein content was determined by Bradford's method (Bradford, 1976), and moisture content was analyzed using AOAC method No. 925.45 (2012). All the recorded data of the aforementioned parameters were statistically analyzed by using statistical software (Statistix 8.1).

## Results

***Gladiolus grandiflora*:** The effect of different extracts on *Gladiolus Grandiflora* showed that the fresh weight of the flowers in the ginger extract treatments, T<sub>1</sub>: 25 ml/L ginger extract (2.5%) and T<sub>2</sub>: 50 ml/L ginger extract (5%), was 90.23±2.95 g and 91.7±3.5 g, respectively (Table 1 and Fig. 1). These weights were significantly higher than the distilled water control (T<sub>0</sub>), which had a fresh weight of 87.67±0.52 g. However, the fresh weight in the lemon extract treatments, T<sub>3</sub>: 25 ml/L lemon (citrus) extract (2.5%) and T<sub>4</sub>: 50 ml/L lemon (citrus) extract (5%), was not significantly different from T<sub>0</sub>. For freshwater uptake, the maximum uptake was observed in T<sub>2</sub> with 27.33±0.88 ml as compared with T<sub>0</sub> (control treatment) with the mean value of 19.06±1.1 ml. The freshwater uptake in T<sub>1</sub> and T<sub>3</sub> was not significantly different from T<sub>0</sub>, while T<sub>4</sub> had a slightly higher uptake compared to T<sub>0</sub> (Table 1 and Fig. 2). The flower head diameter ranged from T<sub>2</sub> (124.27 mm) in T<sub>0</sub> (96.2 mm), indicating a significant increase in flower size with T<sub>2</sub> (Table 1 and Fig. 3). The petal water content ranged from T<sub>0</sub> (1.5%) to T<sub>2</sub> (1.86%), suggesting that T<sub>2</sub> is effective in increasing flower size while maintaining optimal water content (Table 1 and Fig. 4). The mean petal dry weight was highest in T<sub>2</sub> (1.13±0.01 g) and lowest in T<sub>0</sub> (0.76±0.02 g). The treatment T<sub>3</sub> (0.78±0.02 g) and T<sub>4</sub> (0.73±0.01 g) had greater petal dry weight than T<sub>0</sub>, while T<sub>1</sub> (0.88±0.02 g) was higher than T<sub>0</sub> but lower than T<sub>3</sub> and T<sub>4</sub> (Table 1 and Fig. 5). Petal ion leakage was highest in T<sub>0</sub> (154.73±4.92%) and lowest in T<sub>2</sub> (105.25±4.24%). Treatments viz., T<sub>1</sub>, T<sub>3</sub>, and T<sub>4</sub> had lower ion leakage than T<sub>0</sub> but higher than T<sub>2</sub> (Table 1 and Fig. 6). The pH was acidic in T<sub>0</sub> (3.10) but higher in T<sub>1</sub>, T<sub>2</sub>, and T<sub>3</sub>. T<sub>4</sub> had the highest pH value of 5.71, which was significantly higher than all other treatments (Table 1 and Fig. 7). Total soluble solids were minimum in T<sub>0</sub> (3.87±0.39 °Bx) and maximum in T<sub>4</sub> (7.38±0.34 °Bx). T<sub>1</sub>, T<sub>2</sub>, and T<sub>3</sub> all had significantly higher values than T<sub>0</sub> (Table 1 and Fig. 8).

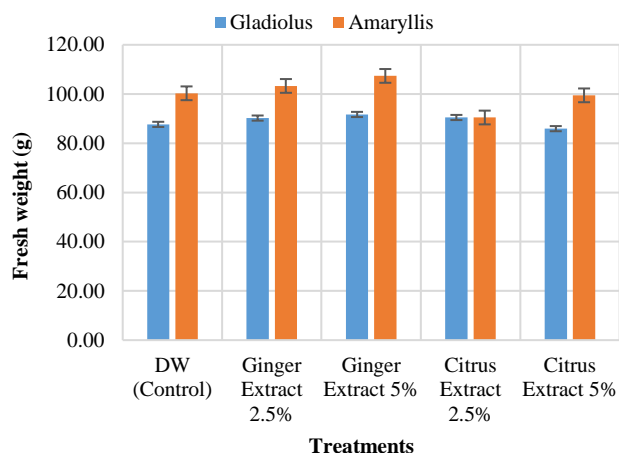


Fig. 1. Effect of Ginger and Citrus extracts on the Fresh Weight (g) of *Gladiolus Grandiflora* and *Amaryllis Belladonna* flowers. Treatments included T0: distilled water, T1: 25 ml/L ginger extract (2.5%), T2: 50 ml/L ginger extract (5%), T3: 25 ml/L lemon extract (2.5%), and T4: 50 ml/L lemon extract (5%).

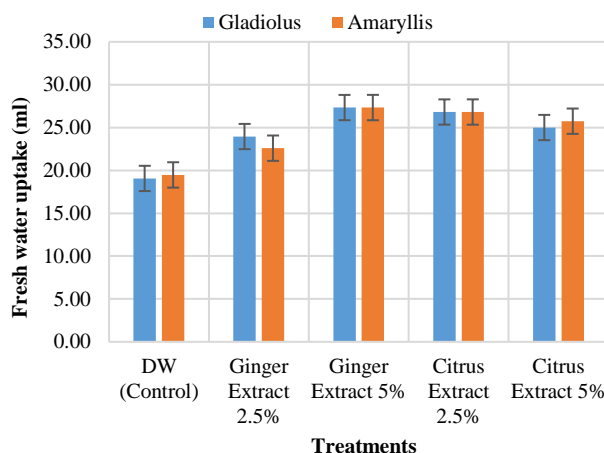


Fig. 2. Effect of Ginger and Citrus extracts on the Water Uptake (ml) of *Gladiolus Grandiflora* and *Amaryllis Belladonna* flowers. Treatments included T0: distilled water, T1: 25 ml/L ginger extract (2.5%), T2: 50 ml/L ginger extract (5%), T3: 25 ml/L lemon extract (2.5%), and T4: 50 ml/L lemon extract (5%).

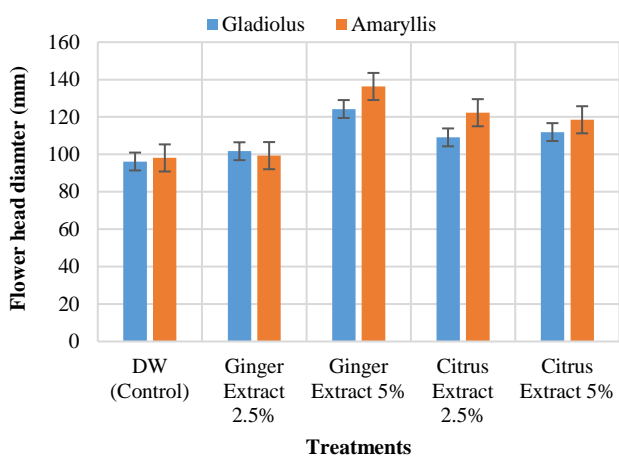


Fig. 3. Effect of Ginger and Citrus extracts on the flower head diameter (mm) of *Gladiolus Grandiflora* and *Amaryllis Belladonna* flowers. Treatments included T0: distilled water, T1: 25 ml/L ginger extract (2.5%), T2: 50 ml/L ginger extract (5%), T3: 25 ml/L lemon extract (2.5%), and T4: 50 ml/L lemon extract (5%).

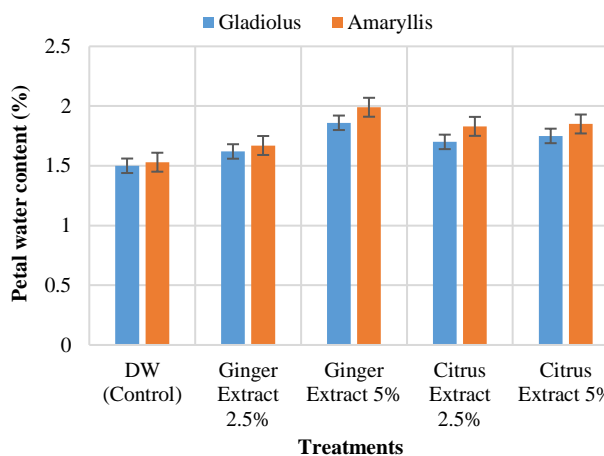


Fig. 4. Effect of Ginger and Citrus extracts on the Petal Water Content (%) of *Gladiolus Grandiflora* and *Amaryllis Belladonna* flowers. Treatments included T0: distilled water, T1: 25 ml/L ginger extract (2.5%), T2: 50 ml/L ginger extract (5%), T3: 25 ml/L lemon extract (2.5%), and T4: 50 ml/L lemon extract (5%).

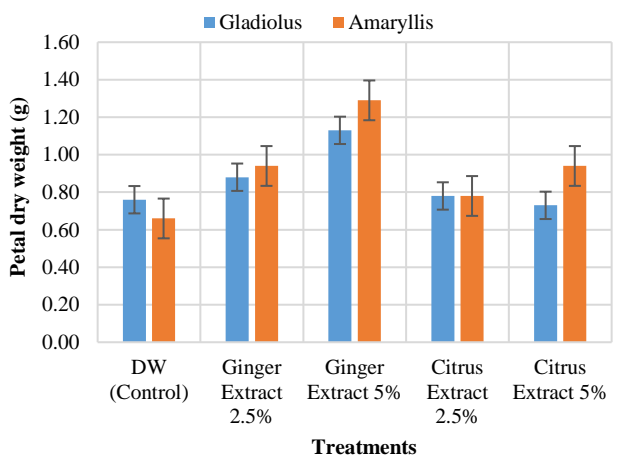


Fig. 5. Effect of Ginger and Citrus extracts on the Petal Dry Weight (g) of *Gladiolus Grandiflora* and *Amaryllis Belladonna* flowers. Treatments included T0: distilled water, T1: 25 ml/L ginger extract (2.5%), T2: 50 ml/L ginger extract (5%), T3: 25 ml/L lemon extract (2.5%), and T4: 50 ml/L lemon extract (5%).

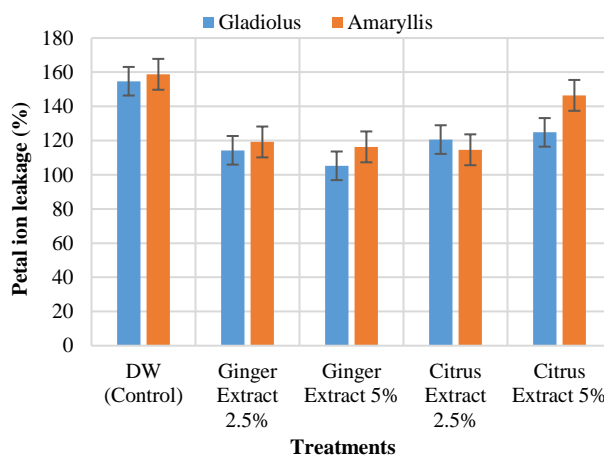


Fig. 6. Effect of Ginger and Citrus extracts on the Petal Ion Leakage (%) of *Gladiolus Grandiflora* and *Amaryllis Belladonna* flowers. Treatments included T0: distilled water, T1: 25 ml/L ginger extract (2.5%), T2: 50 ml/L ginger extract (5%), T3: 25 ml/L lemon extract (2.5%), and T4: 50 ml/L lemon extract (5%).

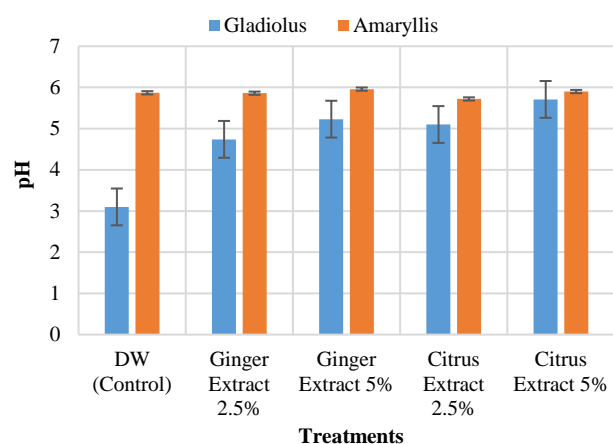


Fig. 7. Effect of Ginger and Citrus extracts on the pH of *Gladiolus Grandiflora* and *Amaryllis Belladonna* flowers. Treatments included T0: distilled water, T1: 25 ml/L ginger extract (2.5%), T2: 50 ml/L ginger extract (5%), T3: 25 ml/L lemon extract (2.5%), and T4: 50 ml/L lemon extract (5%).

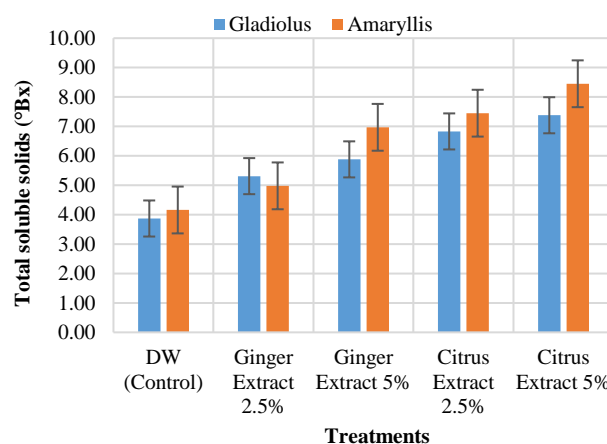


Fig. 8. Effect of Ginger and Citrus extracts on Total Soluble Solids ( $^{\circ}\text{Bx}$ ) of *Gladiolus Grandiflora* and *Amaryllis Belladonna* flowers. Treatments included T0: distilled water, T1: 25 ml/L ginger extract (2.5%), T2: 50 ml/L ginger extract (5%), T3: 25 ml/L lemon extract (2.5%), and T4: 50 ml/L lemon extract (5%).

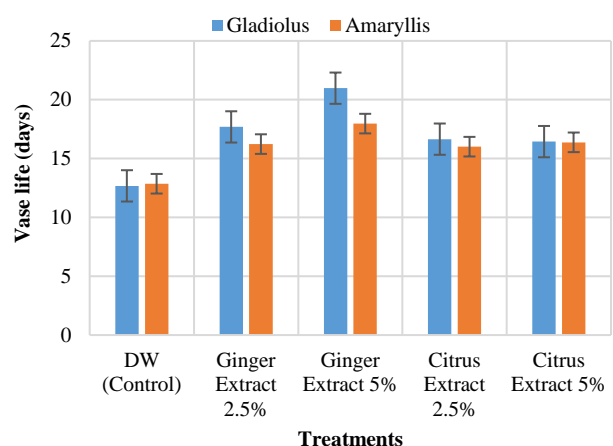


Fig. 9. Effect of Ginger and Citrus extracts on the Vase Life (days) of *Gladiolus Grandiflora* and *Amaryllis Belladonna* flowers. Treatments included T0: distilled water, T1: 25 ml/L ginger extract (2.5%), T2: 50 ml/L ginger extract (5%), T3: 25 ml/L lemon extract (2.5%), and T4: 50 ml/L lemon extract (5%).

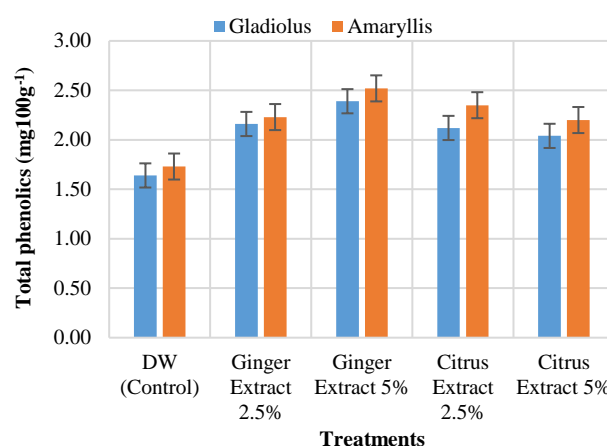


Fig. 10. Effect of Ginger and Citrus extracts on the Total Phenolic Compounds ( $\text{mg}100\text{g}^{-1}$  FW) of *Gladiolus Grandiflora* and *Amaryllis Belladonna* flowers. Treatments included T0: distilled water, T1: 25 ml/L ginger extract (2.5%), T2: 50 ml/L ginger extract (5%), T3: 25 ml/L lemon extract (2.5%), and T4: 50 ml/L lemon extract (5%).

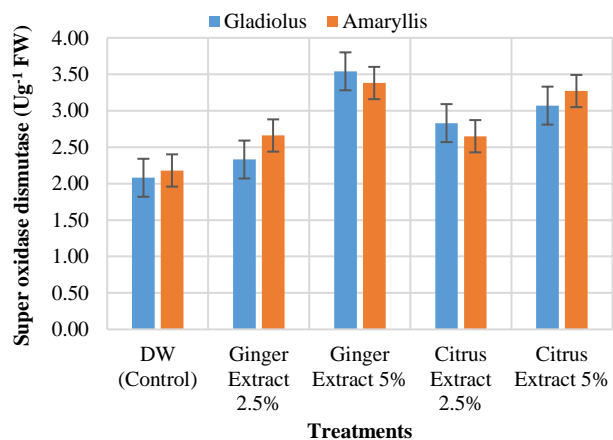


Fig. 11. Effect of Ginger and Citrus extracts on the Superoxide Dismutase (SOD) ( $\text{Ug}^{-1}$  FW) of *Gladiolus Grandiflora* and *Amaryllis Belladonna* flowers. Treatments included T0: distilled water, T1: 25 ml/L ginger extract (2.5%), T2: 50 ml/L ginger extract (5%), T3: 25 ml/L lemon extract (2.5%), and T4: 50 ml/L lemon extract (5%).

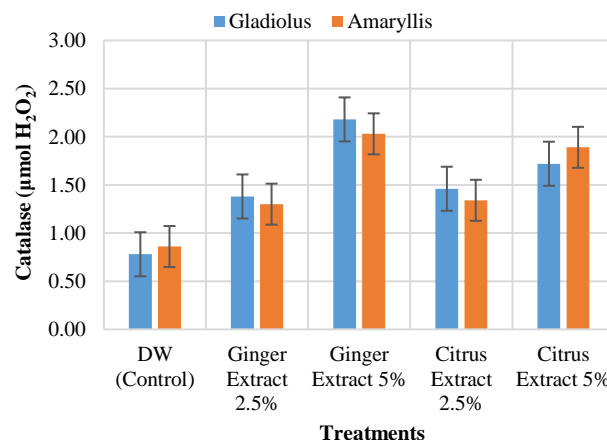


Fig. 12. Effect of Ginger and Citrus extracts on the Catalase Content of *Gladiolus Grandiflora* and *Amaryllis Belladonna* flowers. Treatments included T0: distilled water, T1: 25 ml/L ginger extract (2.5%), T2: 50 ml/L ginger extract (5%), T3: 25 ml/L lemon extract (2.5%), and T4: 50 ml/L lemon extract (5%).

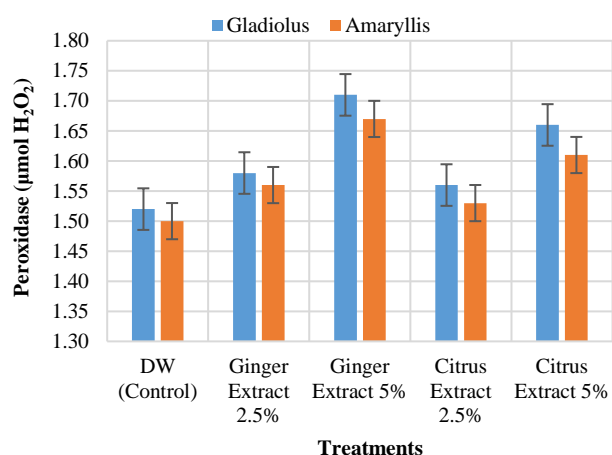


Fig. 13. Effect of Ginger and Citrus extracts on the Peroxidase Content of *Gladiolus Grandiflora* and *Amaryllis Belladonna* flowers. Treatments included T<sub>0</sub>: distilled water, T<sub>1</sub>: 25 ml/L ginger extract (2.5%), T<sub>2</sub>: 50 ml/L ginger extract (5%), T<sub>3</sub>: 25 ml/L lemon extract (2.5%), and T<sub>4</sub>: 50 ml/L lemon extract (5%).

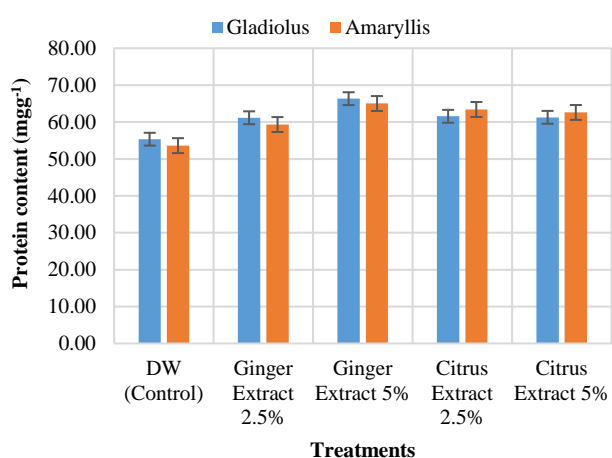


Fig. 14. Effect of Ginger and Citrus extracts on the Protein Content of *Gladiolus Grandiflora* and *Amaryllis Belladonna* flowers. Treatments included T<sub>0</sub>: distilled water, T<sub>1</sub>: 25 ml/L ginger extract (2.5%), T<sub>2</sub>: 50 ml/L ginger extract (5%), T<sub>3</sub>: 25 ml/L lemon extract (2.5%), and T<sub>4</sub>: 50 ml/L lemon extract (5%).

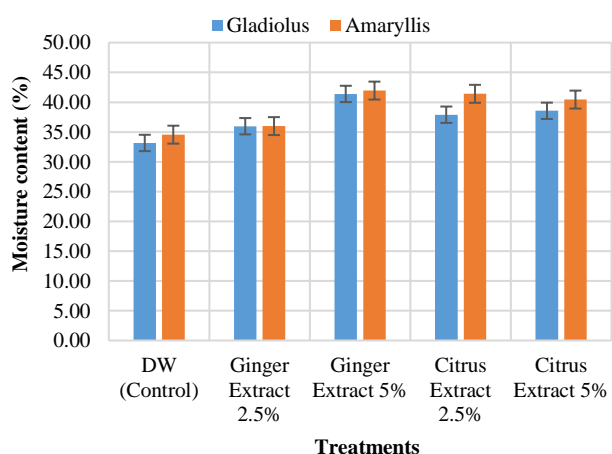


Fig. 15. Effect of Ginger and Citrus extracts on the Moisture Content (%) of *Gladiolus Grandiflora* and *Amaryllis Belladonna* flowers. Treatments included T<sub>0</sub>: distilled water, T<sub>1</sub>: 25 ml/L ginger extract (2.5%), T<sub>2</sub>: 50 ml/L ginger extract (5%), T<sub>3</sub>: 25 ml/L lemon extract (2.5%), and T<sub>4</sub>: 50 ml/L lemon extract (5%).

The longest vase life was observed in T<sub>2</sub> ( $20.98 \pm 0.39$  days), while the shortest was in T<sub>0</sub> ( $12.68 \pm 0.47$  days). T<sub>1</sub> had an intermediate vase life ( $17.69 \pm 0.95$  days), and T<sub>3</sub> and T<sub>4</sub> had similar vase life values ( $16.65 \pm 0.64$  days and  $16.44 \pm 0.45$  days, respectively) (Table 2 and Fig. 9). T<sub>1</sub> showed a mean value of  $2.16 \pm 0.08$  mg  $100\text{g}^{-1}$  FW for total phenolic compounds (TPC) (Table 2 and Fig. 10) and  $2.33 \pm 0.03$   $\text{Ug}^{-1}$  FW for SOD activity (Table 2 and Fig. 10). T<sub>2</sub> had significantly higher TPC than T<sub>0</sub>. T<sub>3</sub> had a TPC of  $2.12 \pm 0.03$  mg  $100\text{g}^{-1}$  FW and SOD activity of  $2.83 \pm 0.07$   $\text{Ug}^{-1}$  FW. T<sub>4</sub> had TPC of  $2.04 \pm 0.04$  mg  $100\text{g}^{-1}$  FW and SOD activity of  $3.07 \pm 0.04$   $\text{Ug}^{-1}$ , both significantly higher than T<sub>0</sub>. T<sub>2</sub> also exhibited the highest activity of catalase ( $2.18 \pm 0.03$   $\mu\text{mol H}_2\text{O}_2$ ) and peroxidase ( $1.71 \pm 0.03$   $\mu\text{mol H}_2\text{O}_2$ ), whereas T<sub>0</sub> had the minimum activity of catalase ( $0.78 \pm 0.06$   $\mu\text{mol H}_2\text{O}_2$ ) and peroxidase ( $1.52 \pm 0.03$   $\mu\text{mol H}_2\text{O}_2$ ) (Table 2 and Figs. 12, 13). T<sub>4</sub> had increased catalase ( $1.72 \pm 0.08$   $\mu\text{mol H}_2\text{O}_2$ ) and peroxidase ( $1.66 \pm 0.03$   $\mu\text{mol H}_2\text{O}_2$ ) activity compared to T<sub>0</sub>. T<sub>1</sub> showed a significant increase in catalase activity ( $1.38 \pm 0.04$   $\mu\text{mol H}_2\text{O}_2$ ) but not in peroxidase ( $1.58 \pm 0.03$   $\mu\text{mol H}_2\text{O}_2$ ); T<sub>3</sub> showed a significant increase in peroxidase activity ( $1.56 \pm 0.01$   $\mu\text{mol H}_2\text{O}_2$ ) but not in catalase ( $1.46 \pm 0.06$   $\mu\text{mol H}_2\text{O}_2$ ). Overall, T<sub>2</sub> and T<sub>4</sub> improved antioxidant capacity. The application of ginger extract and citrus extract also led to a significant increase in protein content, with T<sub>2</sub> having the highest protein content ( $66.33 \pm 1.33$  mg  $\text{g}^{-1}$ ) and moisture content reaching the maximum at  $41.39 \pm 0.64\%$  (Table 2 and Figs. 14, 15).

**Amaryllis belladonna:** The results demonstrate that the fresh weight of the flowers in the 25 ml/L ginger extract (2.5%) (T<sub>1</sub>) and 50 ml/L ginger extract (5%) (T<sub>2</sub>) treatments was  $90.23 \pm 2.95$  g and  $91.7 \pm 3.5$  g, respectively, which was significantly higher than the distilled water control (T<sub>0</sub>) with a fresh weight of  $87.67 \pm 0.52$  g. Conversely, the fresh weight of the 25 ml/L lemon (citrus) extract (2.5%) (T<sub>3</sub>) and 50 ml/L lemon (citrus) extract (5%) (T<sub>4</sub>) treatments was not significantly different from T<sub>0</sub> (Table 1 and Fig. 1). Regarding freshwater uptake, T<sub>0</sub> had the lowest uptake at  $19.06 \pm 1.1$  ml, while the highest uptake was observed in T<sub>2</sub> at  $27.33 \pm 0.88$  ml. Fresh water uptake in T<sub>1</sub> and T<sub>3</sub> was not significantly different from T<sub>0</sub>, whereas T<sub>4</sub> had a slightly higher uptake compared to T<sub>0</sub> (Table 1 and Fig. 2). Flower head diameter ranged from 124.27 mm in T<sub>2</sub> to 96.2 mm in T<sub>0</sub>, indicating a significant increase in flower size with T<sub>2</sub> (Table 1 and Fig. 3). Petal water content ranged from a minimum of 1.5% in T<sub>0</sub> to a maximum of 1.86% in T<sub>2</sub>, suggesting that T<sub>2</sub> effectively increases flower size while maintaining optimal water content. T<sub>1</sub> and T<sub>3</sub> also led to increased flower head diameter but to a lesser extent than T<sub>2</sub>. T<sub>4</sub> did not significantly affect flower size or petal water content (Table 1 and Fig. 4). The mean petal dry weight was highest in T<sub>2</sub> ( $1.13 \pm 0.01$  g) and lowest in T<sub>0</sub> ( $0.76 \pm 0.02$  g). Petal dry weights in T<sub>3</sub> ( $0.78 \pm 0.02$  g) and T<sub>4</sub> ( $0.73 \pm 0.01$  g) were higher than in T<sub>0</sub>, while T<sub>1</sub> ( $0.88 \pm 0.02$  g) was higher than T<sub>0</sub> but lower than T<sub>3</sub> and T<sub>4</sub> (Table 1 and Fig. 5). Petal ion leakage was highest in T<sub>0</sub> ( $154.73 \pm 4.92\%$ ) and lowest in T<sub>2</sub> ( $105.25 \pm 4.24\%$ ). Ion leakage in T<sub>1</sub> ( $114.31 \pm 9.86\%$ ), T<sub>3</sub> ( $120.6 \pm 9.58\%$ ), and T<sub>4</sub> ( $124.8 \pm 4.47\%$ ) was lower than T<sub>0</sub>; but higher than T<sub>2</sub> (Table 1 and Fig. 6). The pH was acidic in T<sub>0</sub> (3.10), but the pH values increased with T<sub>1</sub>, T<sub>2</sub>, and T<sub>3</sub>. T<sub>4</sub> had the highest pH value of 5.71, significantly higher than all other treatments (Table 1 and Fig. 7). Total soluble solids were minimum in T<sub>0</sub> ( $3.87 \pm 0.39$  °Bx) and maximum in T<sub>4</sub> ( $7.38 \pm 0.34$  °Bx). T<sub>1</sub>, T<sub>2</sub>, and T<sub>3</sub> had significantly higher values than T<sub>0</sub> (Table 1 and Fig. 8).

**Table 1. Comparative analysis of the effects of different treatments on the Fresh Weight (%), Water Uptake (ml), flower head diameter (mm), Petal water content (%), Petal dry weight (g), petal ion leakage (%), pH and Total soluble solids (°Bx) of Gladiolus and Amaryllis Flower.**

Flowers	Treatments	Fresh Weight (g)	Fresh Water Uptake (ml)	flower head diameter (mm)	Petal water content (%)	Petal dry weight (g)	petal ion leakage (%)	pH	Total soluble solids (°Bx)
Gladiolus	T <sub>0</sub>	87.67±0.52 <sup>CD</sup>	19.06±1.1 <sup>E</sup>	96.2±3.83 <sup>F</sup>	1.5±0.06 <sup>F</sup>	0.76±0.02 <sup>DE</sup>	154.73±4.92 <sup>A</sup>	3.10 <sup>BC</sup>	3.87±0.39 <sup>F</sup>
	T <sub>1</sub>	90.23±2.95 <sup>CD</sup>	23.95±0.18 <sup>CD</sup>	101.7±5.4 <sup>EF</sup>	1.62±0.07 <sup>DEF</sup>	0.88±0.02 <sup>C</sup>	114.31±9.86 <sup>BC</sup>	4.74 <sup>C</sup>	5.31±0.36 <sup>D</sup>
	T <sub>2</sub>	91.7±3.5 <sup>C</sup>	27.33±0.88 <sup>A</sup>	124.27±0.72 <sup>B</sup>	1.86±0.04 <sup>AB</sup>	1.13±0.01 <sup>B</sup>	105.25±4.24 <sup>C</sup>	5.23 <sup>BC</sup>	5.88±0.16 <sup>CD</sup>
	T <sub>3</sub>	90.47±0.93 <sup>CD</sup>	26.81±0.56 <sup>AB</sup>	109.1±1.99 <sup>DE</sup>	1.7±0.03 <sup>BCD</sup>	0.78±0.02 <sup>D</sup>	120.6±9.58 <sup>BC</sup>	5.1 <sup>C</sup>	6.83±0.2 <sup>BC</sup>
	T <sub>4</sub>	85.93±2.84 <sup>D</sup>	25±1.53 <sup>BC</sup>	111.94±1.21 <sup>CD</sup>	1.75±0.02 <sup>BCD</sup>	0.73±0.01 <sup>DE</sup>	124.8±4.47 <sup>B</sup>	5.71 <sup>AB</sup>	7.38±0.34 <sup>B</sup>
	Mean	97.2±2.15 <sup>B</sup>	24.43±0.85 <sup>A</sup>	108.64±2.63 <sup>B</sup>	1.69±0.04 <sup>B</sup>	0.86±0.0 <sup>B</sup>	123.94±6.62 <sup>B</sup>	5.19 <sup>B</sup>	5.85±0.29 <sup>B</sup>
Amaryllis	T <sub>0</sub>	100.3±0.59 <sup>B</sup>	19.47±0.87 <sup>E</sup>	98.11±3.62 <sup>F</sup>	1.53±0.06 <sup>EF</sup>	0.66±0.06 <sup>E</sup>	158.77±3.29 <sup>A</sup>	5.87 <sup>A</sup>	4.16±0.64 <sup>EF</sup>
	T <sub>1</sub>	103.3±1.1 <sup>AB</sup>	22.59±0.59 <sup>D</sup>	99.33±0.49 <sup>F</sup>	1.67±0.06 <sup>CDE</sup>	0.94±0.01 <sup>C</sup>	119.2±3.48 <sup>BC</sup>	5.86 <sup>A</sup>	4.98±0.35 <sup>DE</sup>
	T <sub>2</sub>	107.37±0.87 <sup>A</sup>	25.97±0.6 <sup>ABC</sup>	136.32±2.11 <sup>A</sup>	1.99±0.08 <sup>A</sup>	1.29±0.09 <sup>B</sup>	116.32±6 <sup>BC</sup>	5.96 <sup>A</sup>	6.97±0.14 <sup>B</sup>
	T <sub>3</sub>	101.9±0.26 <sup>B</sup>	25.98±0.57 <sup>ABC</sup>	122.29±1.06 <sup>B</sup>	1.83±0.08 <sup>ABC</sup>	0.78±0.01 <sup>D</sup>	114.63±6.3 <sup>BC</sup>	5.72 <sup>AB</sup>	7.45±0.14 <sup>B</sup>
	T <sub>4</sub>	99.47±0.54 <sup>B</sup>	25.74±0.61 <sup>ABC</sup>	118.51±2.66 <sup>BC</sup>	1.85±0.04 <sup>AB</sup>	0.94±0.01 <sup>C</sup>	146.45±2.63 <sup>A</sup>	5.9 <sup>A</sup>	8.45±0.15 <sup>A</sup>
	Mean	102.47±0.67 <sup>A</sup>	23.95±0.65 <sup>A</sup>	114.91±1.99 <sup>A</sup>	1.77±0.06 <sup>A</sup>	0.92±0.04 <sup>A</sup>	131.07±4.34 <sup>A</sup>	5.86 <sup>A</sup>	6.4±0.28 <sup>A</sup>

**Table 2. Comparative analysis of the effects of different treatments on the Vase life (days), Total phenolic compounds (mg100g<sup>-1</sup>), Superoxide dismutase (Ug<sup>-1</sup> tissue), Catalase (μmol H<sub>2</sub>O<sub>2</sub>), Peroxidase (μmol H<sub>2</sub>O<sub>2</sub>), Protein Content (mgg<sup>-1</sup>) and Moisture content (%) of Gladiolus and Amaryllis Flowers.**

Flowers	Treatments	Vase life (days)	Total phenolic compounds (mg 100g <sup>-1</sup> )	Superoxide dismutase (Ug <sup>-1</sup> tissue)	Catalase (μmol H <sub>2</sub> O <sub>2</sub> )	Peroxidase (μmol H <sub>2</sub> O <sub>2</sub> )	Protein content (mgg <sup>-1</sup> )	Moisture content (%)
Gladiolus	T <sub>0</sub>	12.68±0.47 <sup>D</sup>	1.64±0.06 <sup>F</sup>	2.08±0.03 <sup>G</sup>	0.78±0.06 <sup>E</sup>	1.52±0 <sup>DE</sup>	55.35±0.83 E	33.16±1.31 F
	T <sub>1</sub>	17.69±0.95 <sup>BC</sup>	2.16±0.08 <sup>DE</sup>	2.33±0.03 <sup>F</sup>	1.38±0.04 <sup>D</sup>	1.58±0.03 <sup>CD</sup>	61.16±0.69 <sup>CD</sup>	35.97±1.41 <sup>DE</sup>
	T <sub>2</sub>	20.98±0.39 <sup>A</sup>	2.39±0.04 <sup>AB</sup>	3.54±0.02 A	2.18±0.03 <sup>A</sup>	1.71±0.03 <sup>A</sup>	66.33±1.33 <sub>A</sub>	41.39±0.64 <sup>A</sup>
	T <sub>3</sub>	16.65±0.64 <sup>BC</sup>	2.12±0.03 <sup>DE</sup>	2.83±0.07 <sup>D</sup>	1.46±0.06 <sup>D</sup>	1.56±0.01 <sup>CDE</sup>	61.56±0.89 <sup>CD</sup>	37.9±0.38 <sup>CD</sup>
	T <sub>4</sub>	16.44±0.45 <sup>BC</sup>	2.04±0.04 <sup>E</sup>	3.07±0.04 <sup>C</sup>	1.72±0.08 <sup>C</sup>	1.66±0.03 <sup>AB</sup>	61.28±0.57 <sup>CD</sup>	38.56±0.4 <sup>BC</sup>
	Mean	16.89±0.58 <sup>A</sup>	2.07±0.05	2.77±0.04 <sup>A</sup>	1.5±0.05 <sup>A</sup>	1.61±0.02 <sup>A</sup>	61.14±0.86 <sup>A</sup>	37.4±0.83 <sup>A</sup>
Amaryllis	T <sub>0</sub>	12.86±0.35 <sup>D</sup>	1.73±0.01 <sup>F</sup>	2.18±0.08 <sup>FG</sup>	0.86±0.06 <sup>E</sup>	1.5±0.01 <sup>E</sup>	53.61±0.64 <sup>E</sup>	34.55±0.42 <sup>EF</sup>
	T <sub>1</sub>	16.23±0.5 <sup>BC</sup>	2.23±0.03 <sup>CD</sup>	2.66±0.06 <sup>DE</sup>	1.3±0.02 <sup>D</sup>	1.56±0.01 <sup>CDE</sup>	59.32±0.84 <sup>D</sup>	35.99±0.77 <sup>DE</sup>
	T <sub>2</sub>	17.97±0.92 <sup>B</sup>	2.52±0.01 <sup>A</sup>	3.38±0.08 <sup>AB</sup>	2.03±0.04 <sup>AB</sup>	1.67±0.01 <sup>AB</sup>	65.02±1.19 <sup>AB</sup>	41.95±0.63 <sup>A</sup>
	T <sub>3</sub>	16.01±0.95 <sup>C</sup>	2.35±0.12 <sup>BC</sup>	2.65±0.15 <sup>E</sup>	1.34±0.08 <sup>D</sup>	1.53±0 <sup>DE</sup>	63.41±1.04 <sup>BC</sup>	41.41±0.69 <sup>A</sup>
	T <sub>4</sub>	16.38±0.61 <sup>BC</sup>	2.2±0.04 <sup>D</sup>	3.27±0.07 <sup>B</sup>	1.89±0.06 <sup>B</sup>	1.61±0.05 <sup>BC</sup>	62.6±0.34 <sup>BC</sup>	40.44±0.81 <sup>AB</sup>
	Mean	15.89±0.66 <sup>B</sup>	2.21±0.04 <sup>A</sup>	2.83±0.09 <sup>A</sup>	1.48±0.05 <sup>A</sup>	1.57±0.02 <sup>B</sup>	60.79±0.81 <sup>A</sup>	38.87±0.67 <sup>A</sup>

Amaryllis flowers in the distilled water control (T<sub>0</sub>) had a vase life of 12.86±0.35 days, whereas those treated with 25 ml/L ginger extract (2.5%) (T<sub>1</sub>), 50 ml/L ginger extract (5%) (T<sub>2</sub>), 25 ml/L lemon (citrus) extract (2.5%) (T<sub>3</sub>), and 50 ml/L lemon (citrus) extract (5%) (T<sub>4</sub>) had longer vase lives of 16.23±0.5, 17.97±0.92, 16.01±0.95, and 16.38±0.61 days, respectively (Table 2 and Fig. 9). Total phenolic compounds were lowest in T<sub>0</sub> (1.73±0.01 mg 100g<sup>-1</sup> FW) and highest in T<sub>2</sub> (2.52±0.01 mg100g<sup>-1</sup> FW), with T<sub>1</sub>, T<sub>3</sub>, and T<sub>4</sub> also showing higher levels compared to T<sub>0</sub> (Table 2 and Fig. 10). T<sub>2</sub> notably enhanced catalase (CAT) and superoxide dismutase (SOD) enzyme activities, indicating its effectiveness in boosting the antioxidant defense of Amaryllis flowers. T<sub>4</sub> also improved SOD and CAT activities, contributing to a longer vase life (Table 2 and Fig. 11, 12). Additionally, T<sub>2</sub> increased peroxidase activity and protein content to 65.02±1.19 mg g<sup>-1</sup>, the highest among treatments (Table 2 and Figs. 13, 14). Moisture content was significantly higher in flowers treated with T<sub>2</sub> and T<sub>4</sub> compared to T<sub>0</sub>, while T<sub>1</sub> and T<sub>3</sub> showed no significant difference from T<sub>0</sub> in moisture content (Table 2 and Fig. 15).

## Discussion

Several treatments were applied to Gladiolus and Amaryllis flowers in order to determine how they would react. There was a difference in response between Gladiolus and Amaryllis plants to the treatments, according to the results. The fresh weight of Gladiolus flowers in the GE 2.5% and GE 5% groups was significantly higher than the CE (2.5% & 5%) and control group (Table 1 and Fig. 1). These findings are consistent with previous studies that have shown the potential of plant extracts in enhancing plant growth and development (Ma *et al.*, 2021). The active compounds in ginger extracts, such as antioxidants and growth regulators, may have played a role in stimulating cell division and elongation, leading to increased fresh weight in the treated flowers. Further, results indicate that the uptake of fresh water was significantly increased by the application of ginger and citrus extracts (Table 1 and Fig. 2). The highest freshwater uptake was observed in Gladiolus flowers treated with 5% GE, followed by CE 2.5% and GE 2.5%. In Amaryllis flowers, the highest freshwater uptake was observed in the GE 5% treatment group, followed by CE

2.5% and CE 5%. These results were in accordance with (Teerarak & Laosinwattana, 2019) who stated that the relative water use efficiency (RFW) and water absorption of fern fronds treated with preservative solutions including essential oils were not significantly different from the control. However, pulsing with 25 g mL<sup>-1</sup> ginger oil and holding in 5 mg L<sup>-1</sup> ginger essential oil increased water uptake. According to (López *et al.*, 2017), ginger essential oil possesses antimicrobial properties, with constituent compounds such as borneol and linalool exhibiting antibacterial properties against certain microorganisms (Nychas *et al.*, 2003). Given that the antibacterial qualities of ginger essential oil may maintain water free of germs and avoid occlusion within the stem, which impedes the flow of water and reduces the turgidity of cut fronds.

Petal water content in Gladiolus and Amaryllis did not differ significantly between treatments (Table 1 and Fig. 4). However, the dry weight of petals in both flowers was significantly influenced by the treatments. Specifically, the application of GE and CE treatments resulted in a significant increase in dry weight in both flowers. In Amaryllis, the highest dry weight was observed in the 5% GE treatment. Conversely, in Gladiolus, the highest dry weight was observed in the 5% CE treatment (Table 1 and Fig. 5). The results indicate that the vase life of Gladiolus and Amaryllis flowers can be significantly improved by applying GE 5% treatment. In both the bottom and upper flowers of all treatments, CAT activity decreased over time, reaching levels closer to the end of the vase life than the initial one (Table 2 and Fig. 1). Earlier claims that reducing the production of hydrogen peroxide and/or boosting the activity of antioxidant enzymes might lengthen the vase life of cut lisianthus were disproved. This beneficial effect of polyamine putrescine was discovered (Ataï *et al.*, 2015). As a result of decreasing H<sub>2</sub>O<sub>2</sub> buildup and increasing CAT activity in petals, SA also increased lifespan in lisianthus (Ataï *et al.*, 2015).

An increase in CAT activity has been linked to an endogenous hydrogen-induced senescence delay in lisianthus (Su *et al.*, 2019). CAT activity in cut peonies was greater in flowers preserved with preservatives, notably NS + S, and increased over time (Rabiza-Swider *et al.*, 2020). The mean vase life of Gladiolus and Amaryllis flowers treated with GE 5% was 20.98±0.39 and 17.97±0.92 days, respectively. These values were significantly higher than the control group (12.68±0.47 for Gladiolus and 12.86±0.35 for Amaryllis). Furthermore, the vase life of Gladiolus flowers was also improved by applying GE 2.5% and CE 2.5% treatments, which resulted in a mean vase life of 17.69±0.95 and 16.65±0.64, respectively (Table 2 and Figure 1). However, the vase life of Amaryllis flowers was not significantly improved by these treatments. On the other hand, CE 5% treatment did not significantly affect the vase life of both flower types compared to the control group. The mean vase life for Gladiolus and Amaryllis flowers treated with CE 5% was 16.44±0.45 and 16.38±0.61, respectively. A similar result of Ahmad & Rab, (2020) they identified in experiment that effect of calcium to improve the post-harvest life of gladiolus, as result indicated that 200 mM calcium increased the vase life (12.33 days) of gladiolus spike. Mehraj *et al.*, (2013)

described that cut white snowball chrysanthemum has a maximum shelf life (13.0 days) of a flower was counted in C4 with 100 parts per million of Sucrose + lemon juice solution, this is due to the presence of citric acid in lemon juice present in vase solution helped to improve cut flowers shelf life (Vahdati *et al.*, 2012).

The enhanced vase life, growth, fresh weight and flower quality are attributable to the beneficial effects of ginger extracts on solution absorption and water balance maintenance (Patil & Reddy, 2005). In addition, the application of various solutions decreased the pH (Table 2), as a decrease in pH decreases ethylene production, pathogen and bacterial growth, and vase life (Srivastava & Dwivedi, 2000). The production of ethylene in high concentrations has a negative impact on flower longevity and accelerates senescence (Marandi *et al.*, 2011). GE 5% and CE 5% extracts increased the SOD enzyme activity in Gladiolus and Amaryllis cut flowers, as the application of GE 5% increased the total flavonoids, phenolics, and enzymatic antioxidant activities and inhibited the activity of polyphenol oxidase (Zhang, 2008; Shabanian *et al.*, 2019). The GE controlled the expression of genes implicated in SOD activity (Zhang, 2008). The results of the present experiment demonstrated that the activity of POD increased with increasing amounts of GE but decreased with decreasing amounts of GE (Table 2). This effect, as discussed by (Schopfer *et al.*, 2001), may be the result of peroxidase catalysis and is crucial to the plant's defence system. GE 5% also preserved the increased CAT activity in the case of stress in cut flowers compared to the control (Table 2 and Figs. 12,13). Ezhilmathi claims that through decreasing reactive oxygen species (ROS), CAT activity also increases the vase life of lily cut flowers (Ezhilmathi *et al.*, 2007). The response induced by gibberellic acid in stress tolerance increased the activity of antioxidants in plants, resulting in the ability of radicals to scavenge oxygen radicals in response to oxidative stress (Table 2 and Fig. 14). Both free radical or excess buildup of reactive oxygen species (ROS) and ROS-independent processes not recognized as part of the suggested GE for senescence contribute to the delay and increase in antioxidant potential (Rosenwasser *et al.*, 2010). The actions of POD and CAT demonstrated stabilising effects (Dhindsa *et al.*, 1981; Mangave *et al.*, 2013). Reduced membrane damage from decreased oxidation of unsaturated fatty acids allows scavenging activity of reactive oxygen species (ROS) and ion leakage to alleviate oxidative stress in freshly cut flowers (Scandalios, 1993). Similarly, postharvest quality was enhanced by CE because it decreased malondialdehyde buildup, decreased chlorophyll a and b retardation, and increased scavenging activities (Teerarak & Laosinwattana, 2019).

## Conclusion

The application of ginger extract (GE) and citrus extracts (CE) treatments have a significant impact on the vase life, biochemical and Postharvest traits of Gladiolus and Amaryllis flowers. The study found that treatment with GE 5% resulted in an increase in fresh weight, water uptake,

flower head diameter, and petal dry weight, while maintaining optimal water content and reducing petal ion leakage. Citrus extract also showed an increase in total soluble solids and petal water content. Meanwhile, GE 2.5% and CE 2.5% resulted in moderate increases in flower size and water uptake, but to a lesser extent than GE 5%. Therefore, the study suggests that the use of GE 5% and CE 5% could be an effective strategy for enhancing the growth and development of Gladiolus and Amaryllis flowers.

**Funding:** This work was funded by the Deanship of Scientific Research (DSR) at King Abdulaziz University, Jeddah, Saudi Arabia, under grant no. (GPIP-950-130-2024)

### Acknowledgment

This project was funded by the Deanship of Scientific Research (DSR) at King Abdulaziz University, Jeddah, Saudi Arabia, under grant no. (GPIP-950-130-2024). The authors, therefore, acknowledge with thanks DSR for technical and financial support.

### References

- Ahmad, I., M. Saleem and J.M. Dole. 2016. Postharvest performance of cut 'White Prosperity' gladiolus spikes in response to nano-and other silver sources. *Can. J. Plant Sci.*, 96(3): 511-516.
- Ahmad, I.J.U.A. 2009. Faisalabad, Pakistan, Ph.D. Diss. Production potential and postharvest management of cut rose flowers in Punjab (Pakistan).
- Ahmad, M. and A. Rab. 2020. Calcium effects post-harvest attributes and vase life of gladiolus using different methods of application. *Pak. J. Bot.*, 52(1): 167-179.
- Alimoradi, M., M. Jafararpoor and A. Golparvar. 2013. Improving the keeping quality and vase life of cut *Alstroemeria* flowers by post-harvest nano silver treatments. *Int. J. Agric. Sci.*, 6(11): 632-635.
- Ataai, D., R. Naderi and A. Khandan-Mirkohi. 2015. Delaying of postharvest senescence of lisianthus cut flowers by salicylic acid treatment. *J. Ornament. Plants*, 5: 67-74.
- Ataai, D., R. Naderi and A. Khandan-Mirkohi. 2015. Exogenous putrescine delays senescence of lisianthus cut flowers. *J. Ornament. Plants*, 5: 167-174.
- Bai, J.G., P.L. Xu, C.S. Zong and C.Y. Wang. 2009. Effects of exogenous calcium on some postharvest characteristics of cut gladiolus. *Agr. Sci. China.*, 8(3): 293-303.
- Basiri, Y., H. Zarei, K. Mashayekhy and M.J. Pahlavany. 2011. Effect of Rosemary extract on vase life and some qualitative characteristics of cut Carnation flowers (*Dianthus caryophyllus* cv. White liberty). *J. Stored Prod. Posthar. Res.*, 2(14): 261-265.
- Bayleyegn, A., B. Tesfaye and T.S. Workneh. 2012. Effects of pulsing solution, packaging material and passive refrigeration storage system on vase life and quality of cut rose flowers. *Afr. J. Biotechnol.*, 11(16): 3800-3809.
- Bazaz, A.M., A. Tehranifar and R. Karizaki. 2015. Use of ethanol, methanol and essential oils to improve vase-life of chrysanthemum cut flowers *Int. Res. J. Basic Appl. Sci.*, 9(8): 1431-1436.
- Bellik, Y. 2014. Total antioxidant activity and antimicrobial potency of the essential oil and oleoresin of *Zingiber officinale* Roscoe. *Asian Pac. J. Trop. Dis.*, 4(1): 40-44.
- Bidarigh, S. 2015. Improvement vase life of chrysanthemum (*Dendranthema grandiflorum* L.) cut flowers using essential oils of geranium, eucalyptus and myrtus. *J. Ornament. Hort.*, 5(4): 213-221.
- Bradford, M.M. 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. *Anal. Biochem.*, 72(1-2): 248-254.
- Braga, P.C., M. Culici, M. Alfieri and M. Dal-Sasso. 2008. Thymol inhibits *Candida albicans* biofilm formation and mature biofilm. *Int. J. Antimicrob. Agents.*, 31(5): 472-477.
- Da Silva, J.T. 2003. The cut flower: postharvest considerations. *J. Biol. Sci.*, 3(4): 406-442.
- Damunupola, J.W. and D.C. Joyce. 2008. When is a vase solution biocide not, or not only, antimicrobial?. *J. Jpn. Soc. Hortic. Sci.*, 77(3): 211-228.
- Darandeh, N. and E. Hadav. 2012. Effect of pre-harvest foliar application of citric acid and malic acid on chlorophyll content and post-harvest vase life of *Lilium* cv. Brunello. *Front. Plant Sci.*, 2: 106.
- Dhindsa, R.S., P.A.M.E.L.A. Plumb-Dhindsa and T.A. Thorpe. 1981. Leaf senescence: correlated with increased levels of membrane permeability and lipid peroxidation, and decreased levels of superoxide dismutase and catalase. *J. Exp. Bot.*, 32(1): 93-101.
- Dineshbabu, M., M.A.N.D. Jawaharlal and M. Vijayakumar. 2002. Influence of holding solutions on the post-harvest life of *Dendrobium* hybrid sonia-17. *South Ind. Hort.*, 50(4/6): 451-457.
- Ezhilmathi, K., V.P. Singh, A. Arora and R.K. Sairam. 2007. Effect of 5-sulfosalicylic acid on antioxidant activity in relation to vase life of *Gladiolus* cut flowers. *Plant Growth Reg.*, 51: 99-108.
- Hashemabadi, D., M. Zarchini, S. Hajivand, Z. Safa and S. Zarchini. 2013. Effect of antibiotics and essential oils on postharvest life and quality characteristics of chrysanthemum cut flower. *J. Ornament. Plants.*, 3: 259-265.
- Hassan, F.A.S., R. Mazrou, A. Gaber and M.M. Hassan. 2020. Moringa extract preserved the vase life of cut roses through maintaining water relations and enhancing antioxidant machinery. *Posthar. Biol. Tech.*, 164: 111156.
- He, S., D.C. Joyce, D.E. Irving and J.D. Faragher. 2006. Stem end blockage in cut *Grevillea* 'Crimson Yul-lo' inflorescences. *Posthar. Biol. Tech.*, 41(1): 78-84.
- Kazaz, S., E.G. Ergür, T. Kiliç and S. Seyhan. 2017. July. Effects of some preservative solutions on the vase life of cut rose flowers. In VII Intern. *Symposium on Rose Res. and Cult.*, 1232: 93-98.
- Kazaz, S., T. Kılıç, E. Doğan and S. Sekmen. 2020. Vase life extension of cut hydrangea (*Hydrangea macrophylla*) flowers. *J. Hort. Sci. Biotech.*, 95(3): 325-330.
- Liang, Z.X., J.Z. Zhang, M.Y. Sun, Y.L. Zhang, X.H. Zhang, H. Li and L. Shi. 2018. Variation of phenolic compounds and antioxidant capacities in different organs of *Lilium pumilum*. *Nat. Prod. Comm.*, 13(6): 1934578X1801300616.
- Liu, D., J. Zou, Q. Meng, J. Zou, W. and Jiang. 2009. Uptake and accumulation and oxidative stress in garlic (*Allium sativum* L.) under lead phytotoxicity. *Ecotox.*, 8: 134-143.
- López, E.I.C., M.F.H. Balcázar, J.M.R. Mendoza, A.D.R. Ortiz, M.T.O. Melo, R.S. Pinales and T.H. Delgado. 2017. Antimicrobial activity of essential oil of *Zingiber officinale* Roscoe (Zingiberaceae). *Amer. J. Plant Sci.*, 8(7): 1511-1524.
- Ma, R.H., Z.J. Ni, Y.Y. Zhu, K. Thakur, F. Zhang, Y.Y. Zhang, F. Hu, J.G. Zhang and Z.J. Wei. 2021. A recent update on the multifaceted health benefits associated with ginger and its bioactive components. *Food Fun.*, 12(2): 519-542.
- Mangave, B.D., A. Singh and M.K. Mahatma. 2013. Effects of different plant growth regulators and chemicals spray on post-harvest physiology and vase life of *heliconia* inflorescence cv. Golden Torch. *Plant Growth Reg.*, 69(3): 259-264.

- Marandi, R.J., A. Hassani, A. Abdollahi and S. Hanafi. 2011. Improvement of the vase life of cut gladiolus flowers by essential oils, salicylic acid and silver thiosulfate. *J. Med. Plants Res.*, 5(20): 5039-5043.
- Mehraj, H., A.F. Ona, T. Taufique, S. Mutahera and A.F.M. Jamal Uddin. 2013. Vase life quality improvement of white snowball using vase life extending solutions. *Bangladesh Res. Pub. J.*, 8(3): 191-194.
- Mesomo, M.C., M.L. Corazza, P.M. Ndiaye, O.R. Dalla Santa, L. Cardozo and A. de Paula Scheer. 2013. Supercritical CO<sub>2</sub> extracts and essential oil of ginger (*Zingiber officinale* R.): Chemical composition and antibacterial activity. *J. Super. Fluids*, 80: 44-49.
- Mohammadi Kabari, S.F. and M. Jadid Soleimandarabi. 2019. Improving *Alstroemeria* vase life by plant extracts and 8-hydroxyquinoline sulfate. *J. Orna. Plants*, 9(1): 1-11.
- Nychas, G.J., P. Skandamis and C. Tassou. 2003. Antimicrobials from herbs and spices Natural antimicrobials for the minimal processing of foods, pp. 176-200.
- Patil, S.R. and B.S. Reddy. 2005. Effect of citric acid and sucrose on post harvest water relations, fresh weight and vase life of golden rod (*Solidago canadensis* L.). *Mysore J. Agric. Sci.*, 39(1): 99-103.
- Rabiza-Swider, J.; E. Skutnik, A. Edrzejuk and A. Łukaszewska. 2020. Postharvest treatments improve quality of cut peony flowers. *Agronomy*, 10: 1583.
- Rahman, M.M., S.H. Ahmad, M.T.M. Mohamed and M.Z. Ab-Rahman. 2019. Improving the vase life of cut Mokara red orchid flower using leaf extracts with silver nanoparticles. Proceedings of the National Academy of Sciences, India Section B: *Biol. Sci.*, 89: 1343-1350.
- Rosenwasser, S., E. Belausov, J. Riov, V. Holdengreber and H. Friedman. 2010. Gibberellic acid (GA 3) inhibits ROS increase in chloroplasts during dark-induced senescence of pelargonium cuttings. *J. Plant Growth Reg.*, 29: 375-384.
- Salmi, M.S., M.F. Hoseini, M. Heidari and M.H. Daneshvar. 2018. Extending vase life of cut rose (*Rosa hybrida* L.) cv. Bacara by essential oils. *Adv. Hort. Sci.*, 32(1): pp.61-70.
- Scandalios, J.G. 1993. Oxygen stress and superoxide dismutases. *Plant Physiol.*, 101(1): 7.
- Schopfer, P., C. Plachy and G. Frahry. 2001. Release of reactive oxygen intermediates (superoxide radicals, hydrogen peroxide, and hydroxyl radicals) and peroxidase in germinating radish seeds controlled by light, gibberellin, and abscisic acid. *Plant Physiol.*, 125(4): 1591-1602.
- Shabaniyan, S., M. Nasr Esfahani, R. Karamian and L.S.P. Tran. 2019. Salicylic acid modulates cutting-induced physiological and biochemical responses to delay senescence in two gerbera cultivars. *Plant Growth Reg.*, 87: 245-256.
- Shanan, T.N., K.S. Emara and S.O. Barakat. 2010. Prolonging vase life of carnation flowers using natural essential oils and its impact on microbial profile of vase solutions. *Australian J. Basic & Applied Sci.*, 4(8): 3559-3574.
- Srivastava, M.K. and U.N. Dwivedi. 2000. Delayed ripening of banana fruit by salicylic acid. *Plant Sci.*, 158(1-2): 87-96.
- Štajner, D. and B. Popović. 2009. Comparative study of antioxidant capacity in organs of different *Allium* species. *Open Life Sci.*, 4(2): 224-228.
- Su, J., Y. Nie, G. Zhao, D. Cheng, R. Wang, J. Chen, S. Zhang and W. Shen. 2019. Endogenous hydrogen gas delays petal senescence and extends the vase life of lisianthus cut flowers. *Posthar. Biol. Technol.*, 147: 148-155.
- Teerarak, M. and C. Laosinwattana. 2019. Essential oil from ginger as a novel agent in delaying senescence of cut fronds of the fern (*Davallia solida* (G. Forst.) Sw.). *Posthar. Biol. Tech.*, 156: 110927.
- Vahdati., N. Mashhadian, A. Tehranifar, H. Bayat and Y. Selahvarzi. 2012. Salicylic and citric acid treatments improve the vase life of cut chrysanthemum flowers. *J. Agric. Sci. Tech.*, 14(4): 879-887.
- Zhang, S. 2008. University of Canterbury. Biological Sciences. Ph.D. Dissertations. Investigations into senescence and oxidative metabolism in gentian and petunia flowers.

(Received for publication 16 May 2024)