

VARIOUS POSTHARVEST HANDLING PROCEDURES EXTEND LONGEVITY OF CUT *Gerbera jamesonii* STEMS

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ABSTRACT

Efficient postharvest handling plays a pivotal role in preserving stem quality, which demands testing novel and cost-effective techniques for extending the postharvest longevity of cut stems. Postharvest management practices are crucial to improve cut stems longevity. Therefore, a study was conducted to evaluate and standardize postharvest handling protocols for cut gerbera stems including harvest stage, handling procedures, vase water quality, pulsing and vase preservatives, floral foam, storage methods and durations and packaging materials. Results demonstrated that stems harvested at partially opened bloom stage had the longest vase life (16.6 d) followed by closed bud stage (15.2 d). Stems kept in distilled water remained fresh for longer (8.4 d vase life) compared to tap water (5.0 d) and canal water (3.2 d). Tap water affected gerbera stems negatively with highest petal necrosis (100%) and highest reduction in flower quality (8.1) among tested water sources. Stems handled wet (in buckets containing water) had longest vase life (15.7 d) with least change in flower quality (7.2). Gerbera stems pulsed with 2% sucrose + 100 mg L⁻¹ aluminum sulphate for 24 h exhibited longest vase life (11.4 d) followed by lemon/lime soda (7 Up) + distilled water (11.2 d). Placement of cut stems in lemon/lime soda + distilled water (33:66) until termination (vase preservatives) exhibited longest vase life (15.9 d) followed by 2% sucrose along with 150 mg L⁻¹ citric acid and 100 mg L⁻¹ aluminum sulphate (15.3 d, respectively) and were statistically similar. Chrysal Clear Professional flower food along with floral foam kept stems fresh and marketable for 16.9 d, while for 15.6 d without foam. Stems stored wet (in buckets containing water) or in a floral box along with 1-MCP card for 2 days exhibited longest vase life (7.8 d and 7.3 d, respectively). Flower heads packed in floral box after being wrapped in polythene sleeves and plugged with cotton tube at base exhibited the longest vase life (6.5 d) when stored for 2 days compared to control (unpacked and unstored stems). In summary, gerbera stems may be harvested at partially opened bloom stage, handled in water (wet) from harvest to marketing and preferably handled in distilled water, pulsed with 2% sucrose + 150 mg L⁻¹ citric acid, 2% sucrose + 100 mg L⁻¹ aluminum sulphate or lemon/lime soda + distilled water (50:50) for 24 h or kept continuously in lemon/lime soda + distilled water (33:66) until termination. Moreover, stems may be kept with floral foam and stored in buckets containing water (wet) preferably with 1-MCP card for two days and packed in floral boxes lined with polythene sleeves to keep stems fresh for longer durations.

Keywords: Floral foam, homemade preservatives, ion leakage, packaging, storage methods, termination symptoms.

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INTRODUCTION

Gerbera (*Gerbera jamesonii* L.), a member of the Asteraceae family, is widely grown for its vibrant colours and joyful appearance (Yoo and Roh, 2015). Effective postharvest management of cut flowers is crucial for maintaining their quality and extending their life span in vases (Usman *et al.*, 2016; Darras, 2021). Gerberas are susceptible to substantial postharvest losses due to stem bending, petal wilting, water stress, and microbial contamination (Parween and Gupta, 2022). Harvesting cut flowers at the optimal growth stage helps guarantee their peak freshness, beauty, and vase life

(Ahmad *et al.*, 2014a). After harvest, the most crucial task is the proper handling of the stems during processing. Wet or dry handling are the two most frequently employed techniques (Zhai *et al.*, 2019). Neglecting proper handling may also invite bacterial contamination (Regan and Dole, 2010). Proper handling practice may enhance vase life and prevent detrimental infections, which deteriorate quality (Ahmad *et al.*, 2012).

Vase water is a critical factor in cut flowers, influencing their overall quality and longevity. The vase life of cut flowers can be greatly impacted by the quality of the vase water, especially salt sensitivity (Ahmad *et*

al., 2013c). Typically, cut flowers are placed in tap water, which can have a varied pH and soluble salt level and contain a variety of types of organic matter, chemicals, and bacteria depending on the source (Carlson and Dole, 2013). Water with higher salt levels can significantly compromise the quality and vase life of flowers (Jezdinsky *et al.*, 2024). In cut flower studies, distilled water usually serves as the control vase solution to ensure reproducibility and comparability; nevertheless, tap water or locally sourced water is sometimes used in daily practice (van Meeteren *et al.*, 2001).

Preservatives for cut flowers commonly consist of a blend of substances including carbohydrates, acidifiers, biocides, and other chemicals (Fatima *et al.*, 2022). Floral holding and vase solutions contain carbohydrates, such as sucrose, which serve as an energy source for the flowers. This aids in maintaining the flowers' hydration and preserving their turgor (Ahmad *et al.*, 2014b). Floral preservatives may contain additional substances, such as ethylene inhibitors, to safeguard against the detrimental impact of ethylene gas (Asif *et al.*, 2016).

Prime advantage of cooling is to delay or slow down metabolism, which may preserve stems quality and extend vase life. It is extremely important to store cut flowers at low temperatures to prevent microbial growth, as well as to minimize ethylene production and enzymes breakdown (Da Silva Vieira *et al.*, 2012). Appropriate packaging material serves as a crucial defense against physical damage, dehydration and microbial contamination during transportation and storage (Thakur, 2020). Floral foam significantly influences postharvest care for cut flowers, providing stability and hydration to extend vase life. Foam can be beneficial to some species as it acidifies the vase solution and provide structural support for delicate stems (Regan, 2008).

Cut gerbera production is relatively new among local growers and stakeholders in Pakistan and limited literature is available to handle its cut stems in local circumstances. Therefore, a study was conducted to optimize postharvest handling protocols for cut gerbera stems. It was hypothesized that implementing appropriate postharvest handling practices for cut gerberas, such as harvest stages, handling procedures, vase water quality, homemade pulse or vase floral preservatives, with or without floral foam, storage methods and durations and optimal packaging materials would extend postharvest longevity and assist in preserving flower quality for longer durations.

MATERIALS AND METHODS

Plant material and experimental conditions: Gerbera (*G. jamesonii* L.) stems were sourced from a private flower farm located in Faisalabad, Punjab, Pakistan. Greenhouse grown stems were harvested at commercial

maturity. Cut gerbera 'Tororosso', 'Madira' and 'Bubble Gum' stems were harvested before 09:00 A.M, kept in buckets containing water after harvest and transported to Commercial Floriculture Laboratory, Institute of Horticultural Sciences, University of Agriculture Faisalabad, within 2-3 hours of harvest. On arrival, stems were recut, removing the lower 2-3 cm, and placed in buckets containing tap water for rehydration for two hours. Later, stems were graded based on stem length and development stage, labeled, recut to a uniform length of 40 cm and placed in respective treatments. In exp. 1 regarding harvest stages, stems were harvested at three different harvest stages: closed bud stage, partially opened bloom stage and fully opened bloom stage, and were placed in glass jars. In 2nd experiment regarding handling procedures, stems were divided into two groups after harvest; half were kept in buckets containing water, while the other half were kept in cardboard boxes. After one hour, half of the stems from floral box were shifted to a bucket containing water, while another half were retained in the floral box. Similarly, half of the stems from bucket were shifted to floral box leaving the other half in the bucket for another one hour. Afterwards, stems were processed and placed in glass jars with two stems in each jar for evaluation until termination. In exp. 3, stems were placed in different sources of vase water: distilled water, tap water and canal water until termination. In exp. 4, stems were placed in freshly prepared pulsing solutions for 24 hrs, containing distilled water (control), 2% and 5% sucrose, 2% sucrose + 100 mg L⁻¹ salicylic acid, 2% sucrose + 150 mg L⁻¹ citric acid, 2% sucrose + 100 mg L⁻¹ aluminum sulphate, lemon/lime soda (7 Up) + distilled water (50:50), 2% sucrose + 4 mL L⁻¹ lemon juice, 2% sucrose + 4 mL L⁻¹ vinegar, 2% sucrose + 2 aspirin tablets, 2% sucrose + 15 mL L⁻¹ bleach, 2% sucrose + 300 mg L⁻¹ gibberellic acid (GA) + 300 mg L⁻¹ benzyl adenine (BA) + 300 mg L⁻¹ citric acid (CA), 2% sucrose + 150 mg L⁻¹ citric acid + 100 mg L⁻¹ aluminum sulphate, and Chrysal Clear Professional flower food. After pulsing, stem ends were washed with water to remove extra solution and shifted to jars containing distilled water until termination. Expt. 5, Vase preservatives: stems were placed in respective treatments, after preparing fresh solutions, distilled water (control), 2% sucrose + 150 mg L⁻¹ citric acid, lemon/lime soda (7 Up) + distilled water (33:66), 2% sucrose + 2 aspirin tablets, 2% sucrose + 100 mg L⁻¹ salicylic acid, 2% sucrose + 100 mg L⁻¹ aluminum sulphate, 2% sucrose + 4 mL L⁻¹ lemon juice, 2% sucrose + 4 mL L⁻¹ vinegar, 2% sucrose + 10 mL L⁻¹ bleach, and Chrysal Clear Professional flower food. Expt. 6, Floral foam: cut stems were placed in jars containing solutions with or without floral foam for each respective treatment, viz. distilled water (control), 2% sucrose + 150 mg L⁻¹ citric acid, 2% sucrose + 100 mg L⁻¹ aluminum sulfate, lemon/lime soda (7 Up) + distilled water (33:66) and Chrysal Clear Professional flower

food. Expt. 7, Storage methods and durations: stems were either shifted to jars (no storage) (control) or placed in cold store at $4 \pm 1^\circ\text{C}$ in buckets containing water (wet), cardboard floral box (dry), or cardboard floral box containing 1-MCP card for 2 and 4 days. Expt. 8, Packaging materials: cut stems were packed in different packaging materials, control (commercially used spent cardboard box without ventilation holes), polythene sleeves, newspaper, and floral cardboard box, with or without cotton tube at stem ends and stored at $4 \pm 1^\circ\text{C}$ for 2 and 4 days. After two and four days, stems were removed from cold storage and shifted to jars. There were five replications of each treatment in all tested experiments having two stems per replication. Stems in glass jars containing distilled water or respective solutions were placed in a vase life evaluation room maintained at $20 \pm 2^\circ\text{C}$ temperature with $50\% \pm 10\%$ relative humidity and provided 12 hours of light supplied through white, fluorescent tubes. Data were collected daily until the end of vase life.

Measurements: Data were collected regarding effects of treatments on different quality parameters including,

Change in fresh weight (g): Fresh weight was measured on day 0 of the experiment and on 7th day using electric weighing balance (A & D Gulf, Model DM-305F). Their difference was calculated between two stems and means were worked out.

$$\text{FW (g)} = (\text{W1} - \text{W2})$$

Flower quality: Flower quality of stems was measured on rating scale of 0-9 as 0=bad quality, 6=medium quality and 9 best quality product (Cooper and Spokas, 1991). From each replication five stems were observed by three independent judges and their averages were calculated.

Dry weight (g): In the end of experiment each stem was taken out for dry weight. After shade drying stems were packed in brown paper bags kept in oven at 70°C for 48 hours. Two stems from each replication were weighed in grams on electric weighing balance (HK-DC-320 AS) and their means were calculated.

Water uptake (mL): The volume of water absorbed during the first seven days of vase life was determined by the volume of vase water remaining on day seven of vase life in each jar containing two stems. Water intake was measured as: Water uptake (mL) = $(S_0 - S_7)$, where S_0 represents the quantity of vase water supplied in each jar on day 0 and S_7 represents the amount consumed on day 7.

Ion leakage (%): Ion leakage of gerbera flowers was measured by rubbing five petals from treatment with sand and washed with distilled water. Washed petals were put in test tubes containing 15 mL of distilled water. Test tubes were placed on an orbital shaker for 10 min and

EC_1 of solution was measured by EC meter (Hanna, HI9811-5). After taking EC_1 test tubes were again placed on an orbital shaker for further 100 min and EC_2 was recorded. Ion leakage (%) was recorded by using formula: **Ion leakage (%) = $\text{EC}_2/\text{EC}_1 \times 100$** (for harvest stage, handling procedures, water quality, pulsing and vase preservative experiments).

Change in solution electrical conductivity EC ($\mu\text{S}\cdot\text{cm}^{-1}$) and pH: Solution EC and pH was measured on day 0 of the experiment and on 50% termination using electrical conductivity meter (Hanna, HI9811-5). Their difference was calculated, and means were worked out.

Vase life (days): Vase life was taken from day of experiment initiation till stems exhibited > 50% termination symptoms. Vase life was measured in days and averages were determined (Ahmad *et al.*, 2013c).

Termination symptoms: Termination symptoms viz. petal necrosis (%), bent neck (%), and stem end decay (%), were recorded when they exhibit on $\geq 50\%$ of stems and average was calculated. Stems showing symptoms were numbered as (1-0) as 1= Yes and 0 = No. Data were collected in percentage.

Statistical analysis: All experiments were set up in a completely randomized design (CRD) with five replications of two stems each. Moreover, the first five experiments, harvest stage, vase water quality, handling procedures, pulsing and vase preservatives, were laid out individually in Completely Randomized design (CRD), while for floral foam, storage methods and durations and packaging materials experiments were used, with five replications of two stems each. Data were subjected to analysis of variance (ANOVA) procedures using General Linear Models procedures and means were separated using Fisher's least significant difference (LSD) test at $P \leq 0.05$ (Steel *et al.*, 1997).

RESULTS AND DISCUSSION

Harvest stage: Stems harvested at partially opened bloom stage exhibited longest vase life (16.6 d) followed by closed bud stage (15.2 d) (Fig. 1A, 2AB). The highest water uptake (105 mL) was recorded in stems harvested at fully opened bloom stage followed by partially opened bloom stage (90 mL) (Table 1). The highest change in flower quality was observed when stems were harvested at fully opened bloom stage (5.7) followed by partially opened bloom stage (5.1). Highest ion leakage was recorded in fully opened bloom stage harvested stems flower petals (152.4%) followed by close bud stage (129.2%). Change in EC, petal necrosis and bent neck had no significant differences among treatments and averaged $8 \mu\text{S cm}^{-1}$, 73.3% and 16.6%, respectively (data not presented) (Table 1).

Harvest stage plays a pivotal role in determining longevity of cut stems. Harvesting at the optimal stage is crucial to keep stems fresh for longer durations without losing visual quality. Early harvesting provides more time for flowers to develop and stems are ready to use when they reach the consumer. Cut stems harvested at early bud stage had longer vase life (5.2 d) compared to those harvested at fully opened flower stage (Ahmad *et al.*, 2014b). Tuberosc stems harvested at two-florets opened stage had a longer vase life than three-five florets opened stage (Asif *et al.*, 2016). Harvesting stems at an early stage of development when lower most buds start showing color had longer vase life by 3.4 d compared to later harvested stems (Ahmad *et al.*, 2014a). Harvesting chrysanthemum flowers at standard stage had longer vase life with better flower quality for longer periods (Yoo and Roh, 2015). These findings are similar to the gerbera stems when harvested at partial bloom stage exhibited longest vase life with least change in flower quality. Flower can be harvested at bud stage without reduction in flower quality and postharvest life; whereas some plant species may show bent necks, abnormal blooming and pigmentation when harvested immature. Harvesting stems at fully bloomed stage results in losing quality as stored carbohydrates in stems may be used by developing flower, which may cause senescence of petals.

Handling procedures: Handling of gerbera stems in water (wet handling) performed best to keep stem fresh for longer durations with longest vase life (15.7 d) for wet-wet and (15.4 d) for wet-dry handling (Fig. 1B, 2CD). Gerbera stems require continuous water uptake to maintain turgidity and freshness. Cut stems when handled dry exhibited the highest change in flower quality (9) and petal necrosis (100%) with shorter vase life (11.1 d). Cut stems kept in wet conditions absorbed more water (108 mL) followed by dry handling (103 mL). Petal wilting and necrosis was least in stems handled in wet conditions (40%) throughout handling and processing (Table 2). Change in EC and bent neck had no significant differences among treatments and averaged $6 \mu\text{S cm}^{-1}$ and 28%, respectively (data not presented).

Several floral crops perform best when handled out of water such as marigolds, snapdragons, selected roses etc.; however, some others cannot withstand dry handling (Ahmad *et al.*, 2012). The findings are similar for dry handling of cut roses as 1-2 hours at 20°C did not significantly affect vase life or overall quality. Dry storage for longer durations resulted in a reduction in vase life and quality (Zhai *et al.*, 2019). Handling cut gerbera stems in a wet paper towel or water for 1-2 hours before display significantly improved the vase life and overall quality of flowers compared to dry handling. Handling of cut snapdragon stems dry or wet after harvest to shipping had no effect on postharvest longevity and vase life averaged 8.4 d. Cut stems of several species

that are sensitive to microbes performed well when handled or stored dry (Regan and Dole, 2010). Storing stems at low temperatures in wet conditions reduces bacterial colonies, delays senescence and prolongs life span (Shahri *et al.*, 2011).

Vase water quality: Cut gerbera stems kept in distilled water resulted in longest vase life (8.4 d) compared to tap water (5.0 d) and canal water (3.2 d) (Fig. 2EF, 3A). Tap water negatively affected cut gerbera stems with highest petal necrosis (100%) and change in flower quality (8.1) (Table 3). The change in EC was highest with tap water ($109 \mu\text{S cm}^{-1}$) followed by canal water ($49 \mu\text{S cm}^{-1}$). Change in EC was lowest in distilled water, which contributed to keeping stems fresh for longer periods. Highest water uptake (73 mL) was recorded when stems were kept in distilled water followed by tap water (63 mL) and canal water (42 mL). Change in fresh weight and bent neck had no significant differences among vase water quality and averaged 5.38 g and 83%, respectively (data not presented).

Vase water quality collected from different sources had also a great impact on longevity of cut flowers. Soft and impurities-free water keep stems fresh for longer durations with enhanced water uptake (van Meeteren *et al.*, 2001). The recent findings on cut gerbera stems are in line with gerberas kept in distilled water had longest vase life followed by those kept in tap water and canal water (van Meeteren, 2008). These results are also similar with findings on cut flowers, placed in different quality vase water treated with either silver nitrate or 8-hydroxyquinoline citrate. The flowers which were kept in silver nitrate-treated water had longer vase life, followed by those in tap water and 8-hydroxyquinoline citrate-treated water (Soltani, 2014). Studies on cut rose also support that the vase water quality play a significant role in postharvest longevity of cut stems. Rose stems placed in commercial preservative or water treated with bleach had longest vase life (Butt, 2005).

Pulsing preservatives: Gerbera stems pulsed with 2% sucrose + 100 mg L^{-1} aluminum sulphate exhibited longest vase life (11.4 d) followed by lemon/lime soda (7 Up) + distilled water (11.2 d) (Fig. 2GH, 3B). Use of 2% sucrose + 150 mg L^{-1} citric acid and Chrysal Clear Professional flower food had 7.3 d vase life and were statistically similar. Use of 2% sucrose + 2 aspirin tablets exhibited shortest vase life (3.7 d) with highest bent neck and petal necrosis (100%) (Table 4). Highest water uptake was recorded for stems pulsed with distilled water (111 mL), followed by 2% sucrose (101 mL). Pulsing with aspirin or bleach deteriorated the flower quality with high change in flower quality (9.0) compared to other tested preservatives. Neck bending was not observed in stems treated with sucrose plus salicylic acid.

Table 1. Effect of various harvest stages on change in fresh weight, water uptake, change in pH, change in flower quality, ion leakage and dry weight of cut gerbera stems at 50% termination. Data represents means of 10 stems.

Harvest stages	Change in fresh weight (g)	Water uptake (mL)	Change in pH	Change in flower quality	Ion leakage (%)	Dry weight (g)
Closed bud stage	5.5 b ^z	81 b	2.02 a	4.5 b	129.2 b	2.3 c
Partially opened (25%) bloom stage	6.9 a	90 b	1.90 a	5.1 ab	123.9 c	2.9 b
Fully opened bloom stage	8.3 a	105 a	1.72 b	5.7 a	152.4 a	3.6 a
Significance ^y	0.0032	0.0016	0.0007	0.029	<0.0001	<0.0001

^zMeans separation within columns by Fisher's LSD at P≤0.05.

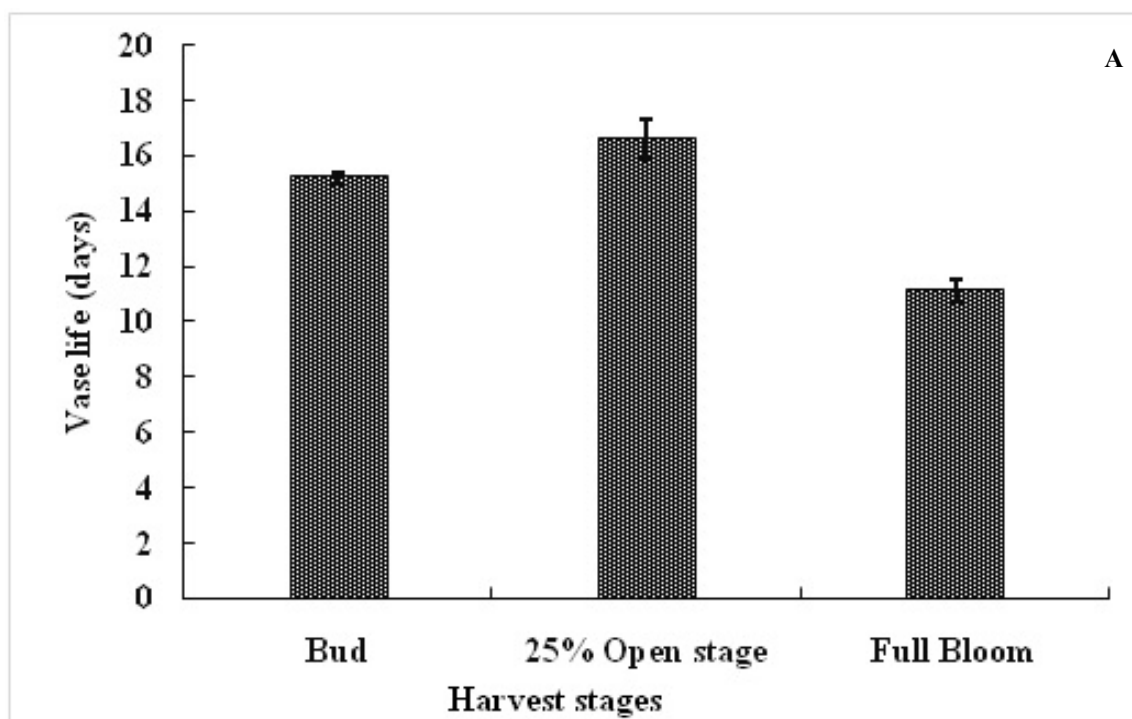
^yP values were obtained using general linear models (GLM) procedures of Statistix (version 8.1, analytical software) for significant effects of different harvest stages on cut gerbera stems.

Table 2. Effect of different handling procedures (wet = stems in buckets of water for 1 h, dry = stems held in floral boxes for 1 h) on change in fresh weight, water uptake, change in pH, change in flower quality, ion leakage, dry weight and petal necrosis of cut gerbera stems at 50% termination. Data represents means of 10 stems.

Handling procedures	Change in fresh weight (g)	Water uptake (mL)	Change in pH	Change in flower quality (1-9)	Ion leakage (%)	Dry weight (g)	Petal necrosis (%)
Wet-Wet	8.5 a ^z	108.0 a	2.4 a	7.2 b	116.9 ab	2.8 b	40 b
Wet-Dry	6.4 b	98.0 bc	1.5 b	7.1 b	144.5 a	3.1 a	70 ab
Dry-Wet	7.7 ab	94.0 c	1.5 b	6.6 b	113.6 b	2.1 c	80 a
Dry-Dry	6.0 b	103.5 ab	1.5 b	9.0 a	99.7 b	2.1 c	100 a
Significance ^y	0.0362	0.0121	<0.0001	0.0070	0.0261	<0.0001	<0.0001

^zMeans separation within columns by Fisher's LSD at P≤0.05.

^yP values were obtained using general linear models (GLM) procedures of Statistix (version 8.1, analytical software) for significant effects of different handling procedures on cut gerbera stems.



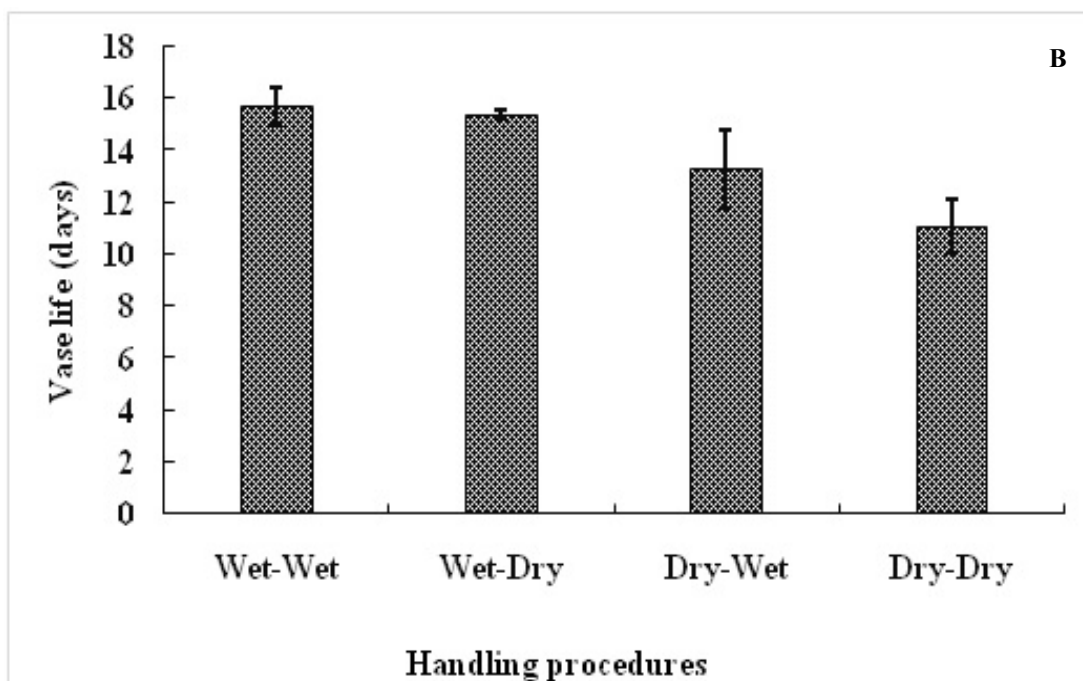


Fig. 1. Effects of various (A) harvest stages and (B) handling procedures (wet = stems in buckets of water for 1 h, dry = stems held in floral boxes for 1 h) on vase life of cut gerbera stems. Bars represent means of 10 stems \pm S.E. (Fig. 1A: Bud = Closed bud stage, 25% open stage = partially opened bloom stage, Full bloom = fully bloomed stage).

Provision of carbohydrates immediately after harvest helps to extend vase life by supporting metabolic processes in cut stems (Tehranifar *et al.*, 2013; Khan *et al.*, 2015). These results are in line with pulsing of cut tuberose spikes with 50 mg L⁻¹ SA with or without 10% sucrose proved effective for extending vase life and improving postharvest performance of cut tuberose spikes (Asif *et al.*, 2016). Similar results were obtained on cut celosia stems pulsed with 5 or 10% sucrose supplemented with antimicrobial agent, for 24 hours had reduced vase life than DI water (Ahmad and Dole, 2014). Homemade pulsing preservatives such as citric acid or aluminum sulfate used along with 2% sucrose or lemon lime soda (7 Up) plus distilled water (50:50) performed best, in extending postharvest longevity of lisianthus, which not only provided carbohydrates to the stems but also controlled microbial growth and acidified the solution for rapid uptake by the cut stems (Fatima *et al.*, 2022).

Vase preservatives: Cut gerbera stems placed in lemon/lime soda (7 Up) + distilled water (33:66) exhibited longest vase life (15.9 d) followed by 2% sucrose + citric acid and aluminum sulphate with (15.3 d), which were statistically similar (Fig. 4AB, 5A). Stems treated with Chrysal Clear Professional flower food exhibited (12.0 d) vase life, while shortest vase life (10.1 d) in stems placed in distilled water (control). Highest water uptake (90 mL) was recorded when stems were placed in sucrose + aluminum sulphate (Table 5). Bleach

and lemon juice affected flower quality negatively by enhancing bent neck and early wilting. The highest bent neck percentage (100%) was observed in stems placed in sucrose + bleach solution followed by sucrose + vinegar (70%). Gerbera stems can be kept fresh when placed in 2% sucrose along with 150 mg L⁻¹ citric acid or 100 mg L⁻¹ aluminum sulphate and lemon/lime soda (7 Up) + distilled water (33:66) with least change in flower quality (3.3), and least change in pH and EC of vase solutions.

Sugars provide signaling molecules and nutrients to plants, in the pathway associated with antioxidant and develop reactive oxygen species (ROS), based upon the amount used in the holding/vase solutions (Bolouri-Moghaddam and van den Ende, 2012). Use of carbohydrates in vase solutions are required to encourage the opening of buds and improve the color and quality of the resulting flowers (Chuang and Chang, 2013; Ahmad *et al.* 2014b). Ahmad *et al.* (2013b) reported that 4% sucrose alone or combined with 100 mg L⁻¹ acetylsalicylic acid, 200 mg L⁻¹ salicylic acid or 600 mg L⁻¹ ascorbic acid resulted in longer vase lives of cut roses. Many commercial floral preservatives are available for use as hydration, holding and vase solutions that are effective and well researched, but, unfortunately, may not be readily available in some parts of world including Pakistan. In such situations, several homemade folk floral preservatives are used, which include various components such as lemon/lime soda, lemon juice,

vinegar, household bleach, and aspirin tablets (Fatima *et al.*, 2022). The use of acidifiers and biocides along with carbohydrates in vase solutions maintain stem and flower turgidity and reduce microbial contamination. Recent findings are in accordance with a study on lisianthus showing that cut stems placed in DW + 7 Up (50:50) had the longest vase life and least change in flower quality

(Ahmad and Dole, 2014). Findings on cut gerbera showed that a preservative solution of chitosan (COS), calcium chloride (CaCl₂) and citric acid (CA) extended vase life of cut gerbera flowers by enhancing antioxidant enzyme activities, which may delay the aging process and extend vase life (Xia *et al.*, 2024).



Fig. 2. Comparison of treatments for (A-B) harvest stage, (C-D) handling procedures, (E-F) vase water quality, and (G-H) pulsing preservatives on cut gerbera stems. (CA = Citric acid, SA = Salicylic acid, ALS = Aluminum sulphate, S = Sucrose, DW= Distilled water).

Table 3. Effect of various vase water sources quality on change in EC (mS.cm⁻¹), water uptake (mL), change in pH, change in flower quality (1-9), ion leakage (%), dry weight (g) and petal necrosis (%) of cut gerbera stems at 50% termination. Data represents means of 10 stems.

Vase water sources	Change in EC (μS.cm ⁻¹)	Water uptake (mL)	Change in pH	Change in flower quality (1-9)	Ion leakage (%)	Dry weight (g)	Petal necrosis (%)
Distilled water	9 c ^z	73 a	3.26 a	2.4 b	141.6 a	3.9 ab	40 b
Tap water	109 a	63 a	1.28 b	8.1 a	86.2 b	3.5 b	100 a
Canal water	49 b	42 b	-0.24 c	4.5 b	69.1 c	4.3 a	10 c
Significance ^y	<0.0001	0.0031	<0.0001	0.0011	< 0.0001	0.0369	<0.0001

^zMeans separation within columns by Fisher's LSD at P≤0.05.

^yP values were obtained using general linear models (GLM) procedures of Statistix (version 8.1, analytical software) for significant effects of vase water quality on cut gerbera stems.

Table 4. Effect of different pulsing preservatives on change in fresh weight (g), change in pH, change in EC (mS cm⁻¹), change in flower quality (1-9) and water uptake (mL) of cut gerbera stems at 50% termination. Data represents means of 10 stems ± S.E.

Pulsing preservatives	Change in fresh weight (g)	Change in pH	Change in EC (μS cm ⁻¹)	Change in flower quality (1-9)	Water uptake (mL)
Distilled water (control)	5.2	-1.50 h ^z	62 cd	5.1 ef	111 a
2% sucrose	4.7	1.80 bc	20 ef	4.2 fg	101 abc
2% sucrose + 100 mg L ⁻¹ salicylic acid	4.1	2.10 a	8.0 f	6.3 cde	108 ab
2% sucrose + 150 mg L ⁻¹ citric acid	4.7	2.00 ab	2.0 f	7.5 bc	105 ab
5% sucrose	4.7	1.96 ab	18 ef	5.4 def	91 bcde
2% sucrose + 100 mg L ⁻¹ aluminum sulphate	4.7	1.90 abc	26 ef	6.3 cde	100 abcd
Distilled water + lemon/lime soda (7 Up) (50:50)	5.4	1.82 bcd	8.0 f	3.3 g	85 cdef
2% sucrose+ 4 mL L ⁻¹ lemon juice	5.6	1.24 fg	70 cd	5.1 ef	72 f
2% sucrose + 4 mL L ⁻¹ vinegar	5.2	1.50 de	88 c	6.3 cde	68 f
2% sucrose + 2 tablets aspirin	4.2	1.60 cde	79 c	9.0 a	83 cdef
2% Sucrose + 15 mL L ⁻¹ bleach	5.7	0.99 g	165 a	9.0 a	90 bcde
2% Sucrose+ citric acid+ gibberellic acid+ benzyl adenine	5.2	1.46 ef	122 b	8.7 ab	73.5 ef
Chrysal Clear Professional flower food	5.5	1.80 bcd	58 cd	6.6 cd	82 def
2% sucrose + citric acid + aluminum Sulphate	4.1	1.82 bcd	41 de	6.6 cd	67 f
Significance ^y	NS	<0.0001	<0.0001	<0.0001	<0.0001

^zMeans separation within columns by Fisher's LSD at P≤0.05.

^yP values were obtained using general linear models (GLM) procedures of Statistix (version 8.1, analytical software) for significant effects of pulsing solutions on cut gerbera stems.

^{NS}Non-significant at P> 0.05.

Floral foam: Floral foam along with preservative extended the vase life of cut gerbera stems. Use of Chrysal Clear Professional flower food or 2% sucrose + aluminum sulphate along with oasis foam had longest vase life (16.9 and 15.0 d, respectively). Lemon/lime soda (7 Up) with or without foam also had similar vase life (14.4 and 14.0 d, respectively) (Fig. 4CD, 5B). Highest water uptake was recorded in sucrose + citric acid without foam (60 mL) followed by Chrysal Clear Professional flower food (55 mL). Least water uptake (22 mL) was recorded in stems kept in distilled water (control) (Table 6). Highest stem end decay (83%) was observed in stems kept in Chrysal Clear Professional

flower food without foam. Bent neck and petal necrosis had no significant differences among tested treatments and averaged 63% and 50%, respectively (data not presented). Floral foam provides essential substrate as well as hydration to cut flowers during display thereby enhancing their longevity by maintaining optimal water uptake. Gerbera stems can be weak and require structural support in floral arrangements. Foam offers structural support, aiding in the arrangement and presentation of cut flowers (Regan, 2008). These findings are in line with the use of traditional phenol-formaldehyde-based floral foam, which maintained vase life longer for most of the flowers tested (Etheredge, 2023). Floral foam has enabled

floral designs to move in extraordinary directions as the process of arranging has become simple for the florists. Floral foam had a positive effect on gerbera vase life;

however, it should be used after thorough soaking in distilled water or floral preservative to keep stems fresh for longer duration.

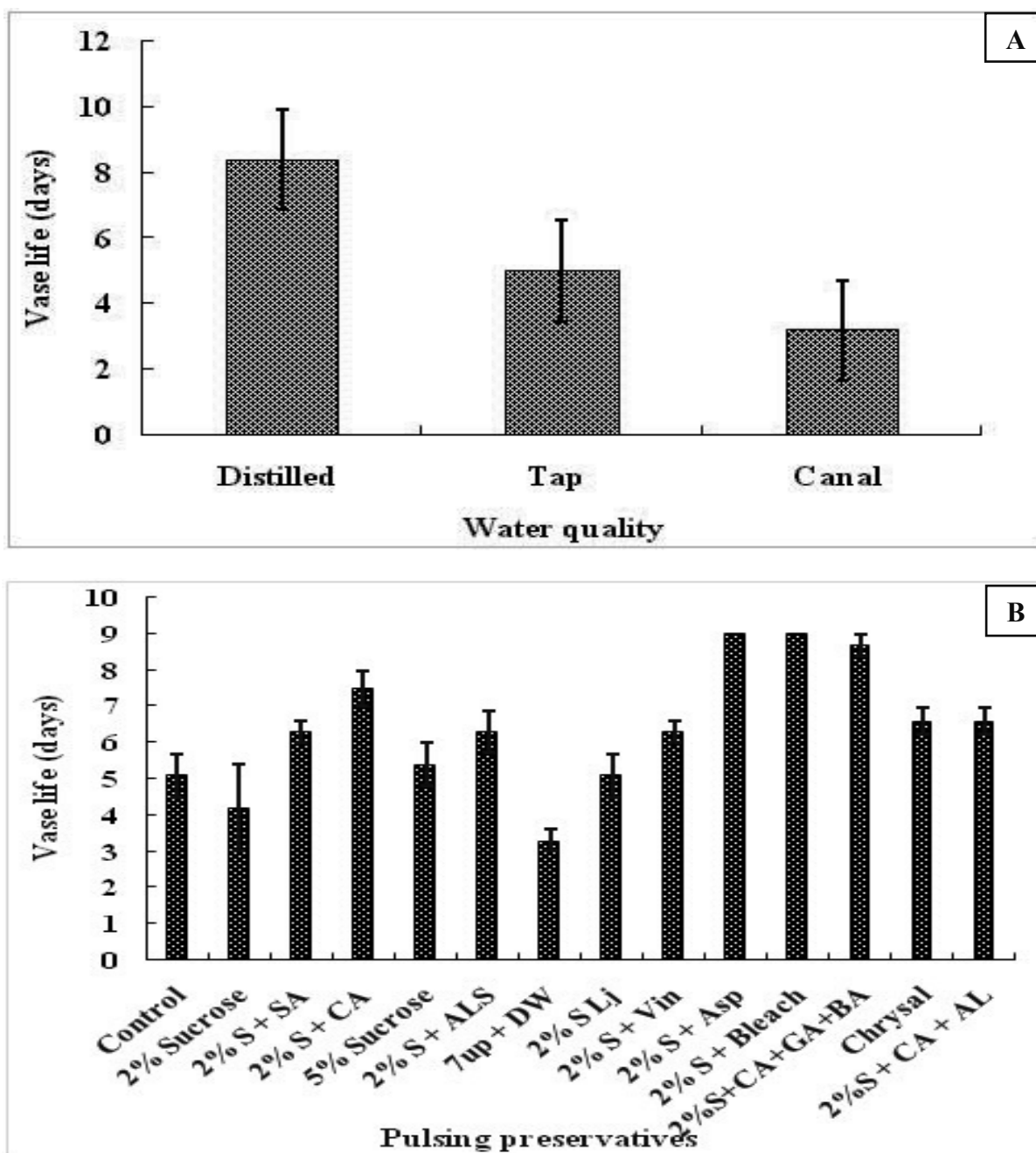


Fig. 3. Effects of various (A) vase water quality and (B) pulsing preservatives on vase life of cut gerbera stems. Bars represent means of 10 stems \pm S.E. (Fig. 2B: S = Sucrose, CA = 150 mg L⁻¹ Citric acid, SA = 100 mg L⁻¹ Salicylic acid, ALS = 100 mg L⁻¹ Aluminum sulphate, DW = Distilled water, Lj = 4 mL L⁻¹ Lemon juice, Vin = 4 mL L⁻¹ Vinegar, Asp = 2tablets/L Aspirin, Bleach = 15 mL L⁻¹, CA + GA + BA = 300 mg L⁻¹ Citric acid +100 gm L⁻¹ Gibberellic acid +100 mg L⁻¹ 1,6-Benzylaminopurine, Chrysal = Chrysal Clear Professional flower food, and CA + AL = 100 mg L⁻¹ Citric acid + 100 mg L⁻¹ Aluminum sulphate)



Fig. 4. Comparison of treatments for (A-B) vase preservatives, (C-D) floral foam, and (E-F) storage methods on cut gerbera stems. (Wet =Wet storage, Dry = Dry storage, 1-MCP = Storage with 1-MCP card, 2D = 2 days, 4D = 4 days). (S = Sucrose, CA = 150 mg L⁻¹ Citric acid, DW = Distilled water, Asp = 2tablets/L Aspirin, SA = 100 mg L⁻¹ Salicylic acid, ALS =100 mg L⁻¹ Aluminum sulphate, Lj = 4 mL L⁻¹ Lemon juice, Vin = 4 mL L⁻¹Vinegar, BL = 10 mL L⁻¹Bleach, Chrysal = Chrysal Clear Professional flower food)

Storage methods and durations along with 1-MCP card: Cut gerbera stems stored in buckets containing water (wet) had longest vase life (7.8 d) when stored for 2 days and 5.8 d for 4 days followed by stems stored dry in floral cardboard box along with 1-MCP card (7.3 d and 5.3 d, for 2- and 4-days storage) compared to control (Fig. 4EF, 7A). Stems stored dry had the shortest vase life with dead flowers after 4 days storage. The greatest water uptake (143 mL) was recorded in unstored stems (control) followed by 138 mL for dry stored stems for 2

days (Table 7). Greatest change in flower quality (8) was recorded in stems stored dry for 4 days. Highest bent neck and petal necrosis (100% each) were recorded when stems were stored dry for 2 and 4 days, respectively. Storage method and duration significantly affected all tested parameters. However, interactive effect was significant only for change in solution EC and pH. Storage of cut stems at low temperature is a pre-requisite as it slows down the metabolic activities, thereby

extending vase life and maintaining quality (Pellegrini and Belle, 2008).

Low temperature storage of cut flowers is important to minimize microbial growth and reduce certain enzymes breakdown and ethylene production (Da Silva Vieira *et al.*, 2012). Majority of major cut flowers should be stored at 1-2°C for longest vase life (Vieira and Brigida, 2009). If cut stems are stored at 10°C or more, vase life is reduced (Vieira and Lima, 2009). Studies on gerbera are in line with campanula in that stems stored at 2°C either wet or dry had no difference in vase life or percent flowers opened; however, flowers stored dry had

a slightly greater percentage of senesced flowers at termination. Gerbera stems stored for 4 days showed more petal necrosis, stem bending and loss in flower quality. These findings are in accordance with studies that increasing storage duration from 1 to 3 weeks decreased vase life (Bosma and Dole, 2002). Wet storage was more effective for maintaining the vase life and quality of cut rose flowers (Abdel-Mawgoud *et al.*, 2015). Flowers stored dry along with 1-MCP card had longer vase life and overall quality as compared to wet storage due to reduced water loss and ethylene production (Wang *et al.*, 2020; Wang *et al.*, 2017).

Table 5. Effect of different vase solutions on change in EC, change in pH, change in fresh weight, change in flower quality and water uptake of cut gerbera stems at 50% termination. Data represents means of 10 stems.

Vase solutions	Change in EC ($\mu\text{S.cm}^{-1}$)	Change in pH	Change in fresh weight (g)	Change in flower quality (1-9)	Water uptake (mL)
Distilled water (control)	-30 ^{bcz}	0.26 ^{bc}	4.9 ^c	6.6 ^b	58 ^{bcd}
2% sucrose + 150 mg L ⁻¹ citric acid	-270 ^{cd}	0.06 ^{bc}	5.1 ^c	6.6 ^b	64 ^{abc}
Lemon/ lime soda (7 Up): distilled water (33:66)	-246 ^{cd}	0.12 ^{bc}	5.9 ^{bc}	3.3 ^d	46 ^{bcd}
2% sucrose + 2 tablets aspirin	-108 ^{bcd}	-1.2 ^d	7.8 ^a	3.0 ^d	38 ^{cde}
2% sucrose + 150 mg L ⁻¹ salicylic acid	-212 ^{cd}	0.58 ^b	6.8 ^{ab}	8.4 ^a	74 ^{ab}
2% sucrose + 100 mg L ⁻¹ aluminum sulphate	-352 ^d	0.40 ^{bc}	5.2 ^c	3.6 ^d	90 ^a
2% sucrose + 4 mL L ⁻¹ lemon juice	108 ^b	-0.4 ^{cd}	5.5 ^{bc}	6.0 ^{bc}	28 ^{de}
2% sucrose + 4 mL L ⁻¹ vinegar	1050 ^a	2.5 ^a	5.8 ^{bc}	6.6 ^b	31 ^{de}
2% sucrose + 10 mL L ⁻¹ bleach	-1598 ^e	-2.4 ^e	5.8 ^{bc}	5.7 ^{bc}	12 ^e
Chrysal Clear Professional flower food	-14 ^{bc}	-0.02 ^d	6.1 ^{bc}	4.5 ^{cd}	43 ^{cd}
Significance ^y	<0.0001	0.0039	<0.0001	0.0061	<0.0001

^yP values were obtained using general linear models (GLM) procedures of Statistix (version 8.1, analytical software) for significant effects of different vase preservatives on post-harvest longevity of cut gerbera stems.

^z Means separation within columns by Fisher's LSD at P \leq 0.05.

Table 6. Effect of various preservative solutions along with floral foam on change in EC, water uptake, change in pH, change in fresh weight, petal necrosis and stem end decay of cut gerbera stems at 50% termination. Data represents means of 10 stems.

Vase preservatives with or without foam Vase solutions	Foam	Change in EC ($\mu\text{S.cm}^{-1}$)	Water uptake (mL)	Change in pH	Change in fresh weight (g)	Petal necrosis (%)	Stem end Decay (%)
Control (distilled water)	No	-5 ^{cdz}	22 ^e	2.4 ^a	6.0 ^a	37	25 ^{cd}
	Yes	475 ^b	146 ^{ab}	0.3 ^b	5.6 ^{ab}	75	37 ^{cd}
2% sucrose + citric acid	No	-72 ^d	60 ^c	0.0 ^f	5.6 ^{ab}	25	75 ^{ab}
	Yes	777 ^a	166 ^a	0.2 ^{cd}	5.3 ^{abc}	50	62 ^{abc}
2% sucrose + aluminum sulphate	No	27 ^{cd}	47 ^{cd}	0.0 ^g	4.8 ^{bcd}	37	12 ^d
	Yes	420 ^b	159 ^{ab}	0.2 ^{bc}	4.6 ^{cde}	75	75 ^{ab}
Lemon/lime soda: distilled water	No	12 ^{cd}	36 ^{de}	0.2 ^{bc}	4.6 ^{cde}	50	75 ^{ab}
	Yes	427 ^b	137 ^b	2.3 ^a	1.3 ^f	50	80 ^{ab}
Chrysal Clear Professional flower food	No	35 ^{cd}	55 ^{cd}	2.7 ^{bc}	4.3 ^{de}	75	83 ^a
	Yes	163 ^c	159 ^a	2.2 ^a	3.8 ^{ef}	26	41 ^{bcd}
Significance ^y							
Vase Solutions (VS)		0.0093	0.0012	<0.0001	<0.0001	NS	0.049
Foam (F)		<0.0001	<0.0001	<0.0001	<0.0001	NS	NS
Vase Solutions (VS) \times Foam (F)		0.0023	NS	<0.0001	NS	0.049	0.031

^z Means separation within columns by Fisher's LSD P \leq 0.05.

^yP values were obtained using general linear models (GLM) procedures of Statistix (version 8.1, analytical software) for significant effects of different floral foam on post-harvest longevity of cut gerbera.

^{NS}Non-significant at P>0.05.

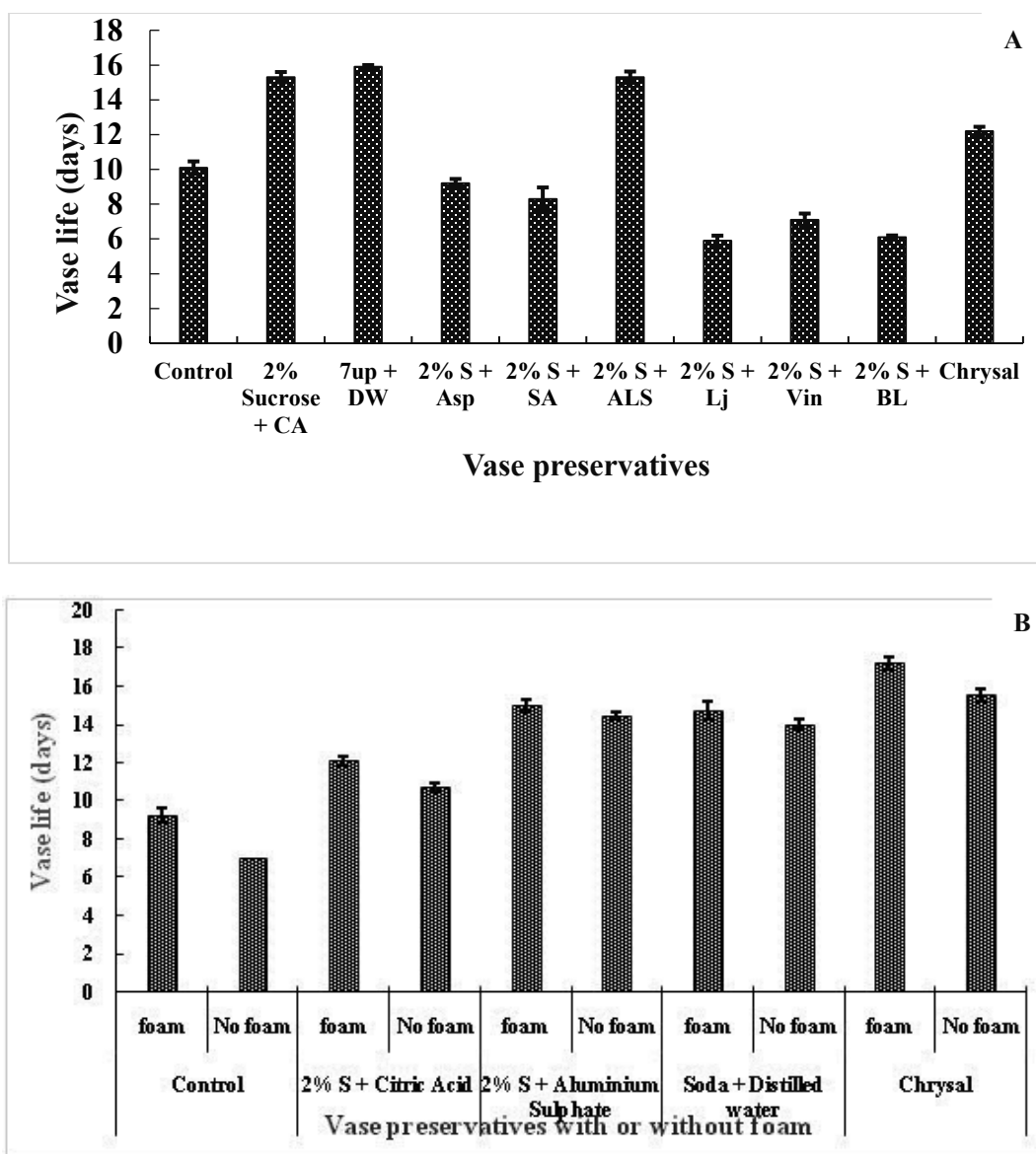


Fig. 5. Effects of various (A) vase preservatives and (B) floral foam along with preservatives on vase life of cut gerbera stems. Bars represent means of 10 stems \pm S.E. (S = Sucrose, CA = 150 mg L⁻¹ Citric acid, DW = distilled water, Asp = 2 tablets/L Aspirin, SA = 100 mg L⁻¹ Salicylic acid, ALS = 100 mg L⁻¹ Aluminium sulphate, LJ = 4 mL L⁻¹ Lemon juice, Vin = 4 mL L⁻¹ vinegar, BL = 10 mL L⁻¹ bleach, and Chrysal = Chrysal Clear Professional flower food).

Packaging materials: Gerbera flowers when packed in floral cardboard box or wrapped with polythene sleeves-maintained freshness and turgidity of stems for 3 days with or without cotton tube. Stems packed in floral box, polythene sleeves or newspaper had similar vase life (3.0 d) along with cotton tube plugged at stem ends and stored for 2 days (Fig. 6AB, 7B). Stems packed in cardboard box had highest water uptake (60 mL) when stored for 4 days followed by 36 mL for 2 days stored stems (Table 8). Least water uptake was recorded for stems stored in polythene sleeve or unstored stems (control). Stem

bending and petal necrosis had no significant differences among tested treatments and averaged 53% and 27%, respectively (data not presented). Polythene packaging may trap ethylene, impacting flower freshness, while floral box packaging provides physical protection but may hinder ventilation. Newspaper wrapping, being porous, facilitates gaseous exchange, reduces ethylene buildup, and helps maintain optimal humidity, positively affecting the post-harvest quality of cut flowers. Careful consideration of packaging materials is essential for gas permeability and moisture retention (Thakur, 2020).

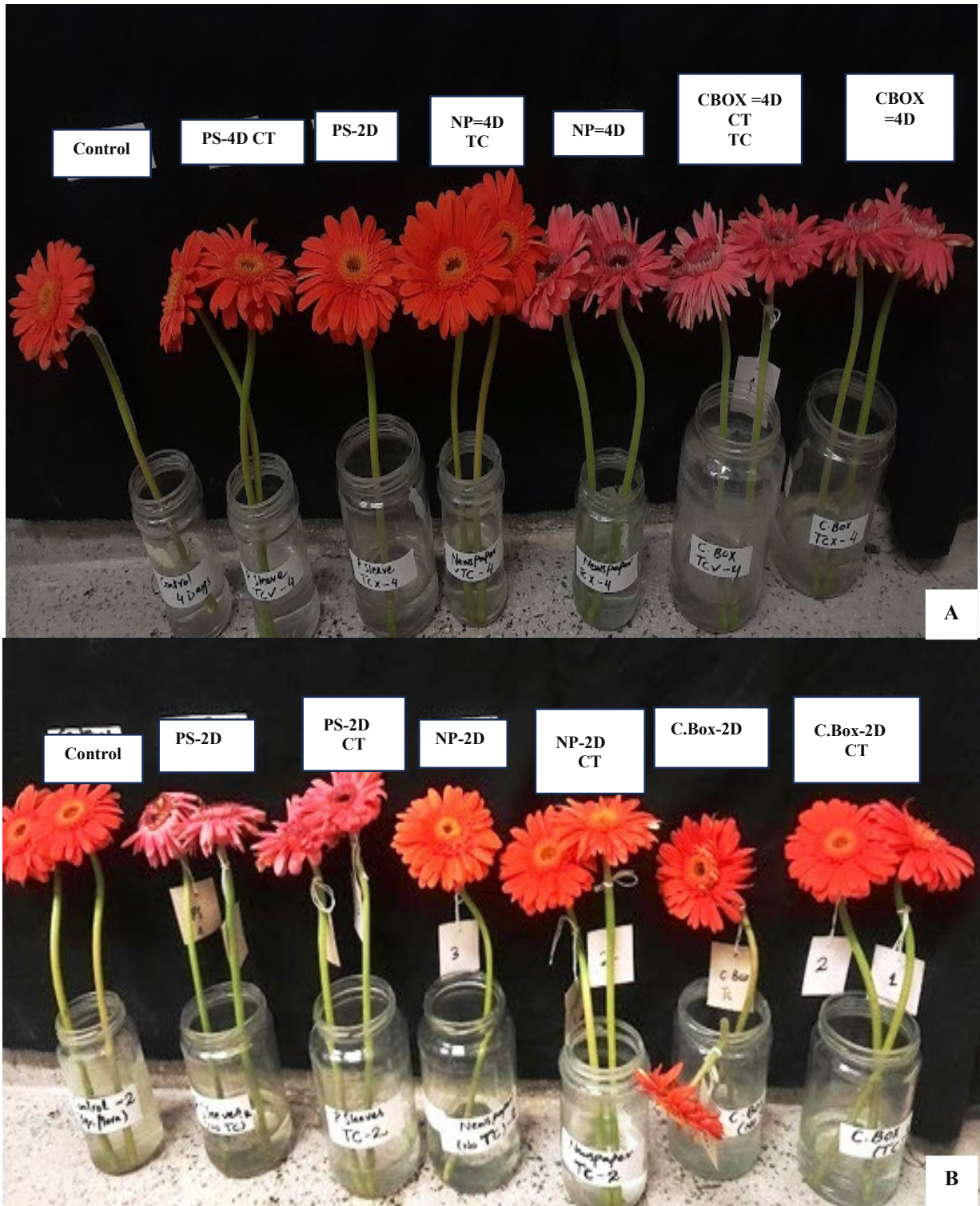


Fig. 6. Comparison of various packaging materials on gerbera stems stored for (A) 2 and (B) 4 days. (PS = Polythene sleeve, NP = Newspaper, C. Box = Cardboard box, CT = Tube cotton, 2D = 2 days, 4D = 4 days).

Table 7. Effect of different storage methods (wet = stems in buckets of water, dry = stems held in floral boxes) and durations (2 or 4 d) along with 1-MCP card on water uptake, change in EC, change in pH, change in flower quality, change in fresh weight, bent neck and petal necrosis of cut gerbera stems at 50% termination. Data represents means of 10 stems.

Treatments	Water uptake (mL)	Change in EC ($\mu\text{S cm}^{-1}$)	Change in pH	Change in flower quality	Change in fresh weight (g)	Bent neck (%)	Petal necrosis (%)
Control (no storage)	143 a ^z	7 c	0.23 c	2 c	3.7 de	0 b	0 b
Wet 2	143 a	10 c	0.03 c	2 c	5.6 a	0 b	0 b
Dry 2	138 a	40 b	0.93 ab	8 a	5.1 abc	0 b	100 a
Dry with 1-MCP card 2	115 bc	10 c	0.13 c	4 bc	5.3 ab	70 ab	67 a
Wet 4	135 a	6.6 c	0.1 c	5 b	4.5 bc	33 ab	67 a
Dry 4	135 a	83.3 a	1.26 a	8 a ^z	3.6 e	100 a	100 a
Dry with 1-MCP card 4	130 ab	10 c	0.86 b	6 ab	4.5 cd	67 ab	66 a
Significance ^y							
Storage method (SM)	0.0012	<0.0001	<0.0001	0.0001	0.0005	0.0174	0.0015
Storage duration (SD)	NS	0.0156	0.0070	NS	0.0003	NS	NS
SM \times SD	NS	0.0012	0.0460	NS	NS	NS	NS

^z Means separation within columns by Fisher's LSD at $P \leq 0.05$.; ^y P values were obtained using general linear models (GLM) procedures of Statistix (version 8.1, analytical software) for significant effects of different storage methods and durations on post-harvest longevity of cut gerbera stems.; ^{NS} Non-significant at $P > 0.05$.

Table 8. Effect of various packaging materials with or without cotton tube on water uptake, change in EC, change in fresh weight, and change in pH of cut gerbera stems at 50% termination. Data represents means of 10 stems.

Packaging materials	Storage duration (days)	Cotton tube	Water uptake (mL)	Change in EC ($\mu\text{S cm}^{-1}$)	Change in fresh weight (g)	Change in pH
Spent cardboard box	2	Yes	26.6 de ^z	36.6 a	4.2	0.7
		No	26.7 de	36.8 a	4.3	0.8
Polythene sleeves	2	Yes	20.0 de	3.3 b	4.8	0.9
		No	10.0 e	0.0 b	4.9	1.0
Newspaper	2	Yes	20.0 de	0.0 b	4.1	1.1
		No	26.6 de	0.0 b	4.0	1.6
Floral cardboard box	2	Yes	36.0 bcd	0.0 b	3.6	1.6
		No	33.0 bcd	0.0 b	4.1	1.2
Spent cardboard box	4	Yes	10.0 e	6.6 b	5.1	1.1
		No	10.0 e	6.6 b	5.0	1.0
Polythene sleeves	4	Yes	50.0 ab	0.0 b	3.7	1.1
		No	30.0 cd	0.0 b	3.6	0.9
Newspaper	4	Yes	26.6 de	0.0 b	4.4	0.9
		No	26.6 de	0.0 b	4.0	1.8
Floral cardboard box	4	Yes	60.0 a	0.0 b	2.6	1.7
		No	46.0 abc	0.0 b	3.5	0.9
Significance ^y						
Packaging materials (PM)			<0.0001	0.0005	NS	NS
Storage duration (SD)			0.0273	0.0453	NS	NS
Cotton tube (CT)			NS	NS	NS	NS
(PM \times SD \times CT)			NS	NS	NS	NS

^z Means separation within columns by Fisher's LSD at $P \leq 0.05$.

^y P values were obtained using general linear models (GLM) procedures of Statistix (version 8.1, analytical software) for significant effects of different packaging materials with or without cotton tube at stem ends on post-harvest longevity of cut gerbera stems. ^{NS} Non-significant at $P > 0.05$.

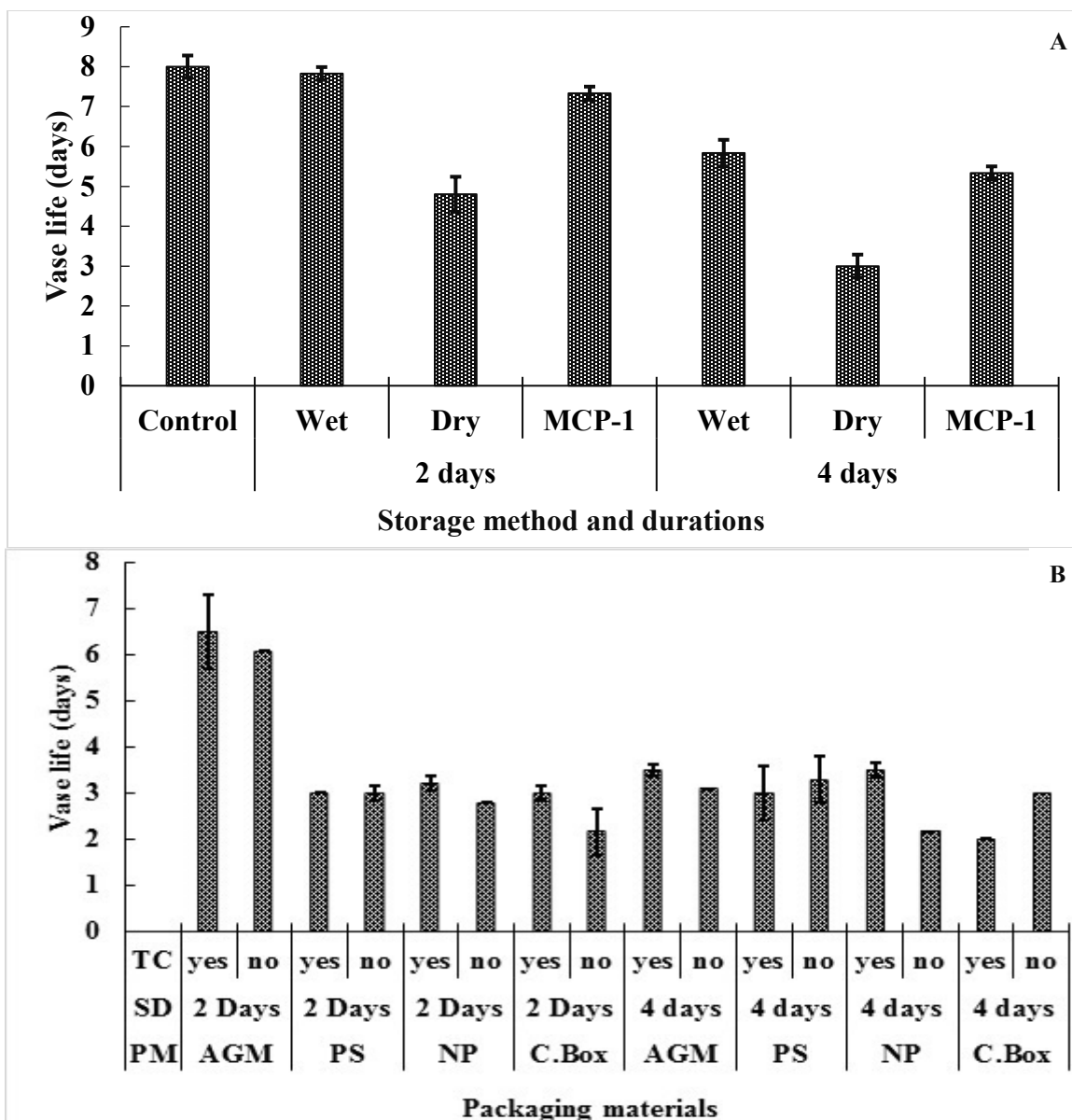


Fig. 7. Effects of (A) storage methods (wet = stems in buckets of water, dry = stems held in floral boxes) & durations and (B) packaging materials on vase life of cut gerbera stems. Bars represent means of 10 stems ± S.E. (Fig. 7A: Control = no storage, Wet = Wet storage, Dry = Dry storage, 1-MCP = Storage with 1-MCP card). (Fig. 7B: SD = Storage durations, PM = Packaging materials, AGM = control method, PS = Polythene sleeves, NP = Newspaper, and C. Box = Floral cardboard box).

Conclusion: Gerbera stems may be harvested at partially-opened bloom stage, handled in buckets containing water (wet handling) from harvest to marketing, using distilled water for handling and should be pulsed with 2% sucrose + 100 mg L⁻¹aluminum sulphate or lemon/lime soda (7 Up) + distilled water (50:50) for 24 hours. Moreover, stems should be kept in 2% sucrose along with 150 mg L⁻¹ citric acid or 100 mg L⁻¹ aluminum sulphate or lemon/lime soda (7 Up) + distilled water (33:66) with floral foam until termination.

Stems should be stored in buckets containing water (wet storage) or in cardboard floral boxes containing 1-MCP card for 2 days and should be packed in floral boxes lined with polythene sleeves or at least newspaper for longest vase life and maintaining the stem quality for longer durations.

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Conflict of interest: The authors declare no conflict of interest.

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