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Streptomycin as alternative postharvest treatment to prolong vase life of gerbera (*Gerbera jamesonii* L.) cut flowers

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Abstract

Background Cut flowers rapidly decline in quality and shorten their vase life after harvest. Various post-harvest methods are being sought to extend their vase life. This study investigated the effects of different storage environments and Streptomycin treatments on postharvest quality and vase life of gerbera flowers. For pre-water absorption treatments, harvested gerbera flowers were all treated with silver thiosulfate (STS 0.2 mM) under room conditions for 6 h. Then, Streptomycin treatments were used alone and combined with sugar at different concentrations in 3 different environments. Their different storage environments were used under room conditions after being kept in STS for 6 h (1st environment), under room conditions after being kept at 2 °C in cold storage for 48 h (2nd environment), storage in cold storage at 2 °C until vase life expires (3rd environment). Vase solution Streptomycin concentrations were 0 (control), 200, 400, and 600 ppm alone, combined with 5% sugar. The experiments were conducted in a completely randomised design (CRD) with three replications and three cut flowers were used in each replication.

Results Streptomycin yielded the best outcomes for vase life especially when it was combined with sugar, increasing the vase life as compared to the control. Compared to the control treatments, with streptomycin treatments, the greatest increase in vase life was observed in 600 ppm Streptomycin + 5% Sugar treatments of the 1st environment (67.5%) (8.22–13.77 days). When the treatments were compared, the longest vase life (13.77 days) was obtained in 600 ppm Streptomycin + 5% Sugar treatment in the 1st environment, the longest vase life (16.67 days) was obtained in 200 ppm Streptomycin + 5% Sugar treatment in the 2nd environment and the longest vase life (73.50 days) was obtained in 600 ppm Streptomycin + 5% Sugar treatment in the 3rd environment. When the environments were compared, the longest vase life (59.17 days) was obtained in the 3rd environment.

Conclusions As a result of this study, it was determined that the use of Streptomycin in combination with sugar gave better results compared to the control group. Streptomycin concentration of 600 ppm is recommended for extending the vase life of cut flowers and this combination may be an alternative and effective method. A streptomycin concentration of 600 ppm at room conditions and 200 ppm at low temperatures such as cold storage is appropriate.

Keywords Anti-bactericide, Vase life, Vase solution, Sugar, Cut flower, Cold storage

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Background

Gerbera (*Gerbera jamesonii* L., *Compositae*) is among the most popular five cut flower species in the world. It is known with high productivity, rich flower colors and alluring appearance [1, 2]. Gerbera (*Gerbera jamesonii* L.) is a perennial species native to Tropical Asia and Africa [3]. This species is an important cut flower with quite a high demand in domestic and foreign markets for fresh and dried flowers, aesthetic decoration, and bouquet making [4].

Improving cut flowers' post-harvest durability and quality is the most important goal. Long vase life and proper opening of flower buds are important quality criteria for consumers [5]. Post-harvest of cut flowers is an active process that includes various physiological and biochemical changes [6]. One of the most important factors affecting cut flowers is temperature. Low-temperature application after harvest slows down metabolic processes such as respiration and sweating, reducing the activity of carbohydrate and other substance reserves, water, ethylene production, and microorganisms [7, 8]. Therefore, the flowers' life is extended, increasing the products' marketing potential. This is especially important in short-lived cut flower species [9].Cold storage is one of the basic techniques used to preserve cut flowers. The temperature range that flowers can be exposed to during cold storage is related to the chill sensitivity of the species [10]. The way low temperature affects the overall longevity and vase life performance of cut flowers depends on the species' biological response, temperature level and storage time [9]. As noted, the vase life of plants previously stored in the cold is often shortened compared to freshly picked flowers, and the strength of this reaction is determined by the storage temperature and duration [9, 11]. Other studies have shown that the increase in temperature during storage reduces the vase life [7, 9, 12]. In general, a temperature between 0 °C and 1 or 2 °C is recommended for the most popular temperate species [10, 13]. Sugars are an integral part of flower food, providing the cut stems with the necessary carbohydrates, which in turn prolongs the continuation of metabolic processes and vase life. Sugars should be used with antimicrobial compounds to prevent microbial accumulation in solutions [14]. Among these antimicrobial compounds, silver compounds such as silver nitrate and silver thiosulfate, and chlorine compounds such as sodium hypochlorite and sodium dichloroisocyanurate are used to inhibit microbial growth in vase solutions [15]. To prevent microbial proliferation, a new antibacterial 'streptomycin' has started to take its place among the compounds.

Streptomycin is the first discovered aminoglycoside antibiotic originally isolated from the bacterium '*Streptomyces griseus*' [16]. Streptomycin belongs to a group of compounds known and manufactured as antibiotics. It prevents the growth and development of microorganisms and even results in total elimination of microorganisms [17]. It was also reported that streptomycin had additional activity against couple aerobic gram-negative bacteria [16, 18]. Antibiotics are often supplemented into the embryo culture medium to prevent bacterial and fungal contamination. Penicillin and streptomycin are the most widely used antibacterial agents [19]. In fact, such antibacterial agents prevent the clogging of xylem vessels and sucrose is generally considered as a source of nutrient. Water balance is preserved in this way; thus, these substances are widely preferred [20].

Studies on increasing the vase life of cut flowers have gained a momentum in recent years. However, present literature reviews revealed that use of streptomycin alone and/or together with sugar supplementation is not common in ornamental plants and there a limited number of studies on extending the post-harvest life of cut flowers. Therefore, this study was conducted to investigate the effects of different vase solutions on postharvest life (vase life) and quality of gerbera plant.

Materials and methods

Plant material

Gerbera (*Gerbera jamesonii* L.) flowers used in this study were supplied from a commercial greenhouse dealing with Gerbera production in Tokat/Türkiye. Harvest was performed in the early morning hours and care was taken to ensure that the plants were healthy, homogeneous and had two rows of male organs.

Experimental design and treatments

Harvested flowers were transported to the laboratory in buckets filled with silver thiosulfate. For pre-water absorption treatments, all plants were treated with 0.2 mM silver thiosulfate at room conditions (room temperature was 25 ± 2 °C, relative humidity value was 50 ± 5% (Hobo Data Logger U12-012) and photoperiod duration was 12 h) for 6 h [21]. The experimental design with three environments was as follows (Fig. 1):

– 1. *Environments*: At the end of the 6th hour in the environment, plants were kept under room conditions, and quality parameters were then analyzed.

– 2. *Environments*: Following the silver thiosulfate treatment, plants were kept in cold storage at 2 °C under 12/12 light/dark photoperiod and 1000 lx light intensity for 48 h. After 48 h, the plants were kept under room conditions, and quality parameters were then analyzed.

– 3. *Environments*: Following the silver thiosulfate treatment, plants were kept in cold storage at 2 °C under 12/12 light/dark photoperiod and 1000 lx light intensity until the end of the vase life. Quality parameters were monitored throughout the storage period.

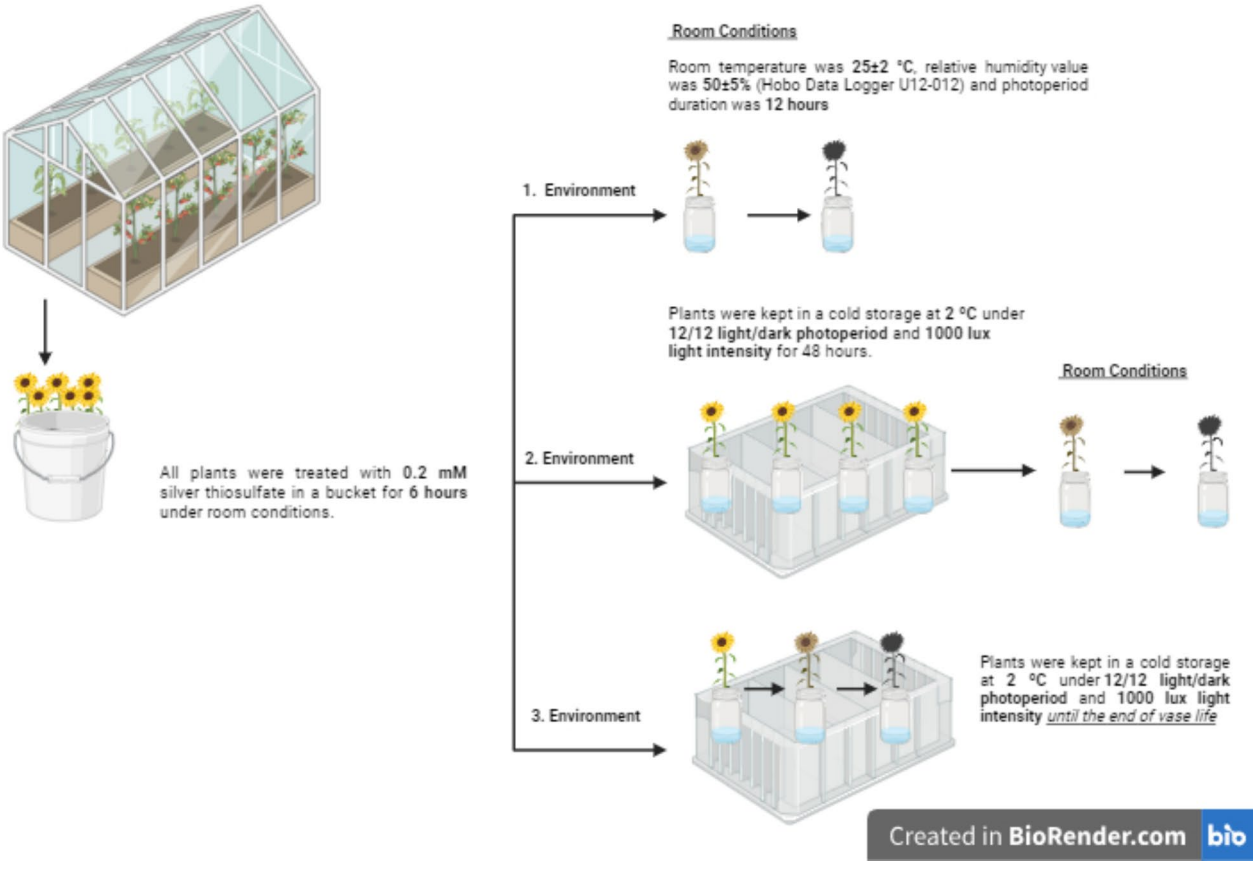

Fig. 1 Experimental design with three environments

Table 1 Vase solutions and concentrations

Treatment	Concentration
(T1) Distilled water (Control) (mL)	-
(T2) Streptomycin (mgL^{-1})	200
(T3) Streptomycin (mgL^{-1})	400
(T4) Streptomycin (mgL^{-1})	600
(T5) Streptomycin (mgL^{-1}) + Sugar (gL^{-1})	200 + 50
(T6) Streptomycin (mgL^{-1}) + Sugar (gL^{-1})	400 + 50
(T7) Streptomycin (mgL^{-1}) + Sugar (gL^{-1})	600 + 50

In the study, keeping the flowers in cold storage at 2 °C was done to prolong the storage period before sale by the producers. In this way, it will be possible to predict how long the flowers can stay at 2 °C.

Gerbera cut flowers were all cut into 40 cm length and placed into seven different vase solutions containing streptomycin (Sigma) and sugar-supplemented combinations (Table 1). The content of all vase solutions was determined as 500 mL.

Throughout the vase life study, in the 1st and 2nd environments, room temperature was 25 ± 2 °C, relative humidity value was 50 ± 5% (Hobo Data Logger U12-012) and photoperiod duration was 12 h Tokat Gaziosmanpasa University, Agriculture Faculty, Horticulture Department).

Vase life (day)

Vase life is defined as the number of days from the day the flowers were placed into the vase (onset) to the day when the flowers were wilting and/or the flower stalk is bent more than 90° [22].

Relative fresh weight (RFW)

In the 1st and 2nd environments, relative fresh weight (RFW) was measured on day 0 (onset) and on days 2, 4, 6 and 8 following the initiation of experiments. In the 3rd environment, data were obtained on the 8th, 16th, 24th, 32nd and 40th days. Calculations were made with the use of the following equation [23]:

$$\mathrm{RFW}\ (\%) = (\mathrm{Wt}/\mathrm{Wt0}) \times 100$$

Wt: Stalk weight at day t (2, 4, 6, etc.)
Wt0 = Stalk weight at day 0.

Daily vase solution uptake (DVSU)

Daily vase solution uptake was calculated with the use of the following equation [24]:

$$\mathrm{DVSU} = (\mathrm{WSt} - 1) - (\mathrm{WSt})$$

WSt-1 = Previous day weight of vase solution.
WSt = Weight of vase solution on day t (2, 4, 6, etc.).

Total vase solution uptake (TVSU)

Total vase solution uptake was calculated with the use of the following equation [24]:

$$\mathrm{TVSU} = \mathrm{A} - \mathrm{B}$$

A: Weight of vase solution at onset.
B: Weight of vase solution at the end of vase life.

Bacteria counts of vase solutions

Bacterial density of vase solutions with different concentrations was calculated by performing a dilution series. Nutrient Agar (NA) was used as the medium in this part of the study. On the last day of vase life, 1 ml vase solution samples were taken and transferred into the tubes containing 9 ml of physiological saline (0.85% NaCl solution-saline buffer). This process was done 6 times. From the −5 and −6 series of the dilution series, 100 µl was taken with a micropipette and placed into 90 mm diameter petri dishes containing NA medium and the suspension was spread with a sterile glass rod. Following the incubation of samples at 37 °C for 24 h, bacterial colonies developed in the petri dishes were counted to get bacterial density of vase solutions [25]. Following the identification of bacterial density, selections were made from bacterial colonies grown in Nutrient Agar medium and the colonies were purified. Selected isolates were diagnosed with the use of MALDI-TOF MS method (at Plant Health Clinic Application and Research Center of Mustafa Kemal University).

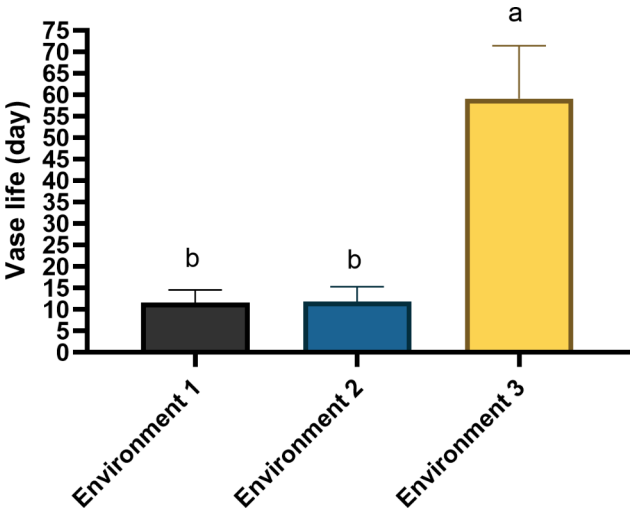

Fig. 2 The effect of different environments of vase life of Gerbera flower vase life (day). *(1) Environment*: Room conditions, *(2) Environment*: Cold storage at 2 °C after 48 h room conditions, *(3) Environment*: Cold storage at 2 °C until vase life expires. Different letters indicate significant differences in each trait according to Duncan's test at $p < 0.05$

Statistical analysis

The experiments were carried out in a completely randomized design (CRD) with three replications and three cut flowers in each replication. Vase life was measured daily and other parameters were measured every two days. The results obtained were evaluated by analysis of variance (ANOVA) in SPSS (IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp.) statistical program. Duncan multiple comparison test was applied to determine the significance of the differences between treatments.

Results

Vase life

Effects of different environments on vase life were investigated in this study. There were significant differences in vase life values of the environments ($p < 0.001$). The longest vase life was achieved in 3rd environment (59.17 days) and the other two environments were not significantly different (Fig. 2).

There were significant differences in vase life of 7 different treatments under 3 environments ($p < 0.001$). In the 1st environment, the longest vase life (13.77 days) was obtained from T7 treatments, and the shortest vase life (8.22 days) was obtained from T1 treatments. In the 2nd environment, the longest vase life (16.67 days) was obtained from T5 treatments, and the shortest vase life (7.67 days) was obtained from T1 treatments. In the 3rd environment, the longest vase life (73.50 days) was obtained from T7 treatments, and the shortest vase life (45.29 days) was obtained from T1 treatments (Fig. 3).

Relative fresh weight

Effects of different environments on the relative fresh weight of gerbera flowers were found to be significant on the 2nd, 4th, 6th, and 8th days ($p < 0.001$). The greatest relative fresh weights were obtained from the 1st environment on the 2nd day and from the 1st and 3rd environments on the 6th and 8th day. The lowest relative fresh weights were obtained from the 2nd environment on all days (Fig. 4).

Effects of experimental treatments on relative fresh weights were found to be significant on all days of the 1st and 2nd environments ($p < 0.001$), but only 32nd day of the 3rd environment.

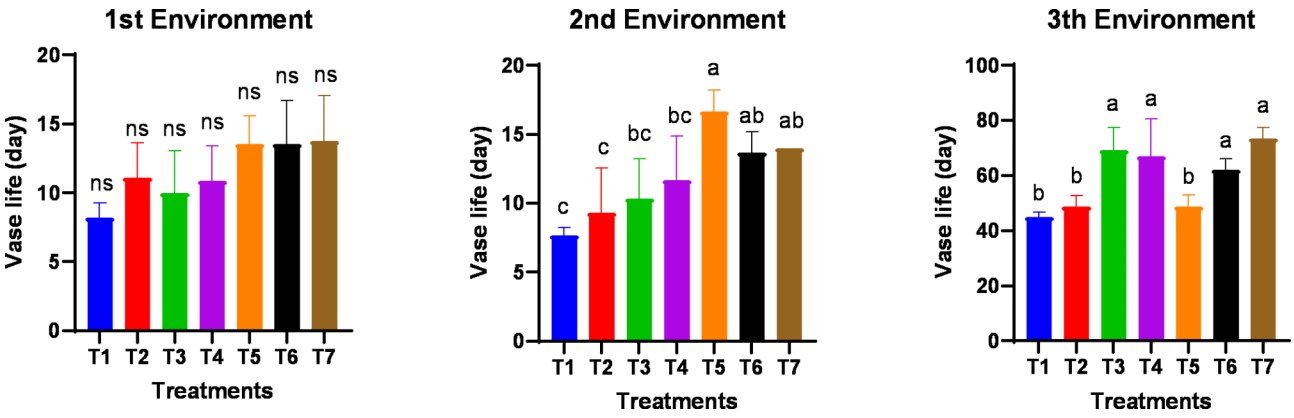

Fig. 3 Effect of different solutions on vase life of Gerbera flowers (day). *T1*: Distilled water, *T2*: 200 mg L^{-1} Streptomycin, *T3*: 400 mg L^{-1} Streptomycin, *T4*: 600 mg L^{-1} Streptomycin, *T5*: 200 mg L^{-1} Streptomycin + 50 g L^{-1} Sugar, *T6*: 400 mg/L Streptomycin + 50 g L^{-1} Sugar, *T7*: 600 mg L^{-1} Streptomycin + 50 g L^{-1} Sugar. (*1. Environment*: Room conditions, *2. Environment*: Cold storage at 2 °C after 48 h room conditions, *3. Environment*: Cold storage at 2 °C until vase life expires). Different letters indicate significant differences in each trait according to Duncan's test at $p < 0.05$. ns: non-significant

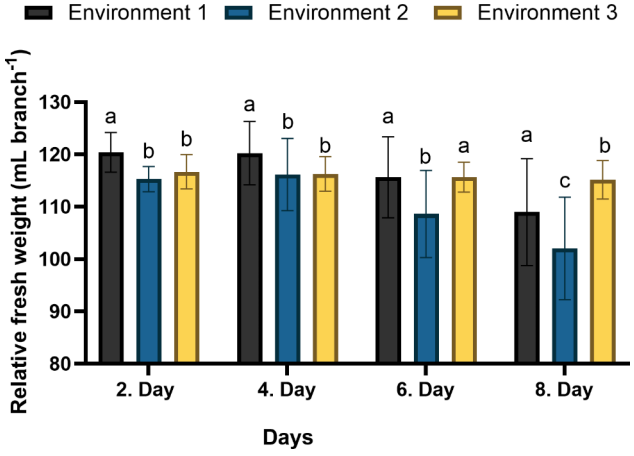

Fig. 4 Effects of different environments on relative fresh weight of Gerbera (*Gerbera jamesonii*) flowers (%). (*1. Environment*: Room conditions, *2. Environment*: Cold storage at 2 °C after 48 h room conditions, *3. Environment*: Cold storage at 2 °C until vase life expires). Different letters indicate significant differences in each trait according to Duncan's test at $p < 0.05$

In the 1st environment, the greatest relative fresh weights were obtained from T7 treatments on all days (122.78-126.92-126.56-120.59%). The lowest relative fresh weights were obtained from T5 treatments on the 2nd day (114.86%), from T2 treatments on the 4th day (119.57%), from T1 treatments on the 6th and 8th days (107.12-100.27%) (Fig. 5).

In the 2nd environment, the greatest relative fresh weights were obtained from T4 treatments on the 2nd day (117.33%) and from T7 treatments on the 4th, 6th, and 8th days all days (121.38-118.16-113.10%). The lowest relative fresh weights were obtained from T1 treatments on the 2nd, 4th, and 6th days (112.80-107.55-99.81%) and from T3 treatments on the 8th day (30.47%) (Fig. 6).

In the 3rd environment, the greatest relative fresh weights were obtained from T1 treatments on the 8th and 16th days (120.06–118.05%) and from T6 treatments on the 24th and 32nd days (117.30-118.59%). The lowest relative fresh weights were obtained from T5 treatments on the 8th and 16th days (114.16-114.67%) and from T1 treatments on the 24th and 32nd days (114.11-110.62%) (Fig. 7).

Daily vase solution uptake

Effects of different environments on daily vase solution uptake values were found to be significant for all days, except for 2-4th day ($p < 0.001$). The greatest daily vase solution uptake (2.90 g) was obtained from 0-2nd day of the 1st environment and decreasing water uptakes were seen in the other days and environments. By the 8-10th day, the greatest water loss (-3.91 g) was seen in the 2nd environment (Fig. 8).

In the 1st environment, the effects of different vase solution treatments on daily vase solution uptake values were found to be significant in 0-2nd day, 2-4th day, and 4-6th day samples ($p < 0.05$). By 0-2nd day, the greatest daily vase solution uptake (3.37 g) was observed in T7 treatments, and the lowest value (2.13 g) was seen in T5 treatments. By the 8-10th day, there was no vase solution uptake, and losses were encountered. The lowest water loss (-0.84 g) was seen in T6 treatments, and the greatest water loss (-7.11 g) was seen in T1 treatments (Table 2).

In the 2nd environment, effects of different vase solution treatments on daily vase solution uptake values were found to be significant in 0-2nd day, 2-4th day, 4-6th day, and 8-10th day samples ($p < 0.05$). By 0-2nd day, the greatest daily vase solution uptake (2.89 g) was observed in T4 treatments, and the lowest value (1.88 g) was seen in T3 treatments. By 8-10th day, no vase solution uptake and losses were encountered. The lowest water loss (-0.62 g) was seen in T3 treatments, and the greatest water loss (-11.26 g) was seen in T1 treatments (Table 3).

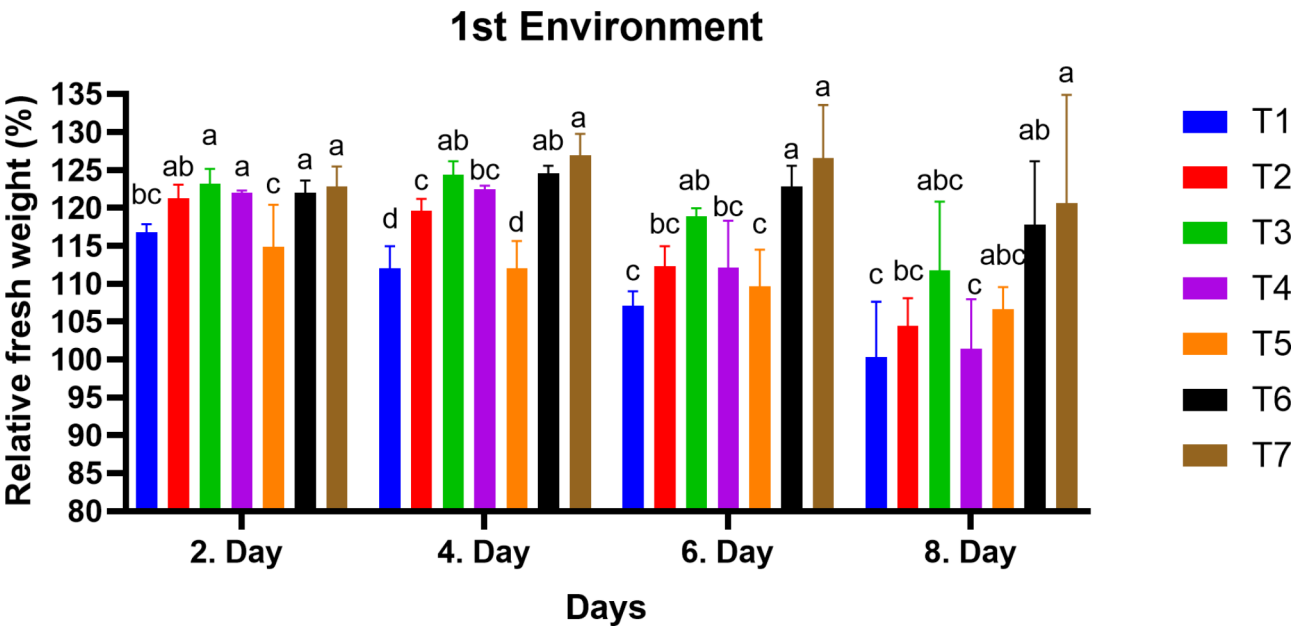

Fig. 5 Effect of different vase solutions on relative fresh weight of *Gerbera* flowers (%). *T1*: Distilled water, *T2*: 200 mg L^{-1} Streptomycin, *T3*: 400 mg L^{-1} Streptomycin, *T4*: 600 mg L^{-1} Streptomycin, *T5*: 200 mg L^{-1} Streptomycin + 50 g L^{-1} Sugar, *T6*: 400 mg/L Streptomycin + 50 g L^{-1} Sugar, *T7*: 600 mg L^{-1} Streptomycin + 50 g L^{-1} Sugar. (*Environment 1*: Room conditions). Different letters indicate significant differences in each trait according to Duncan's test at $p < 0.05$

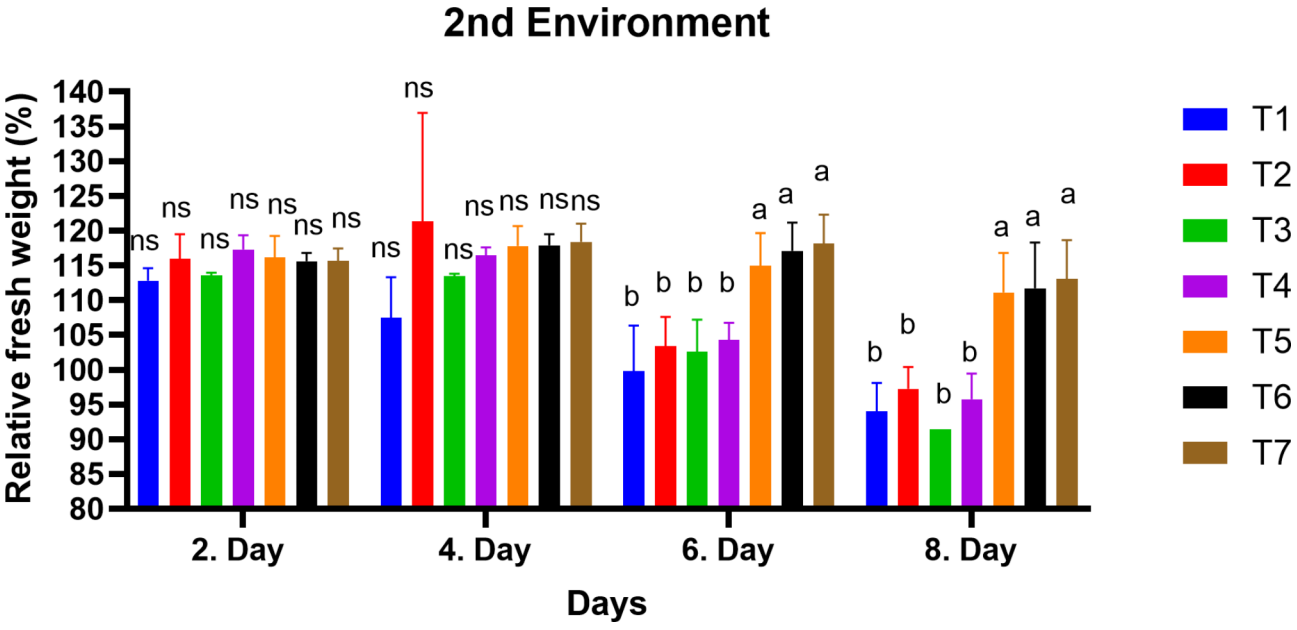

Fig. 6 Effect of different vase solutions on relative fresh weight of *Gerbera* flowers (%). *T1*: Distilled water, *T2*: 200 mg L^{-1} Streptomycin, *T3*: 400 mg L^{-1} Streptomycin, *T4*: 600 mg L^{-1} Streptomycin, *T5*: 200 mg L^{-1} Streptomycin + 50 g L^{-1} Sugar, *T6*: 400 mg/L Streptomycin + 50 g L^{-1} Sugar, *T7*: 600 mg L^{-1} Streptomycin + 50 g L^{-1} Sugar. (*2. Environment*: Cold storage at 2 ºC after 48 h room conditions). Different letters indicate significant differences in each trait according to Duncan's test at $p < 0.05$. ns: non-significant

In the 3rd environment, effects of different vase solution treatments on daily vase solution uptake values were found to be significant only in 0-2nd day ($p < 0.05$). By 0-8th day, the greatest daily vase solution uptake (2.70 g) was observed in T4 treatments, and the lowest value (1.91 g) was seen in T5 treatments. By 32-40th day, there was no vase solution uptake and losses were encountered. The lowest water loss (-0.06 g) was seen in T6 treatments, and the greatest water loss (-0.82 g) was seen in T7 treatments (Table 4).

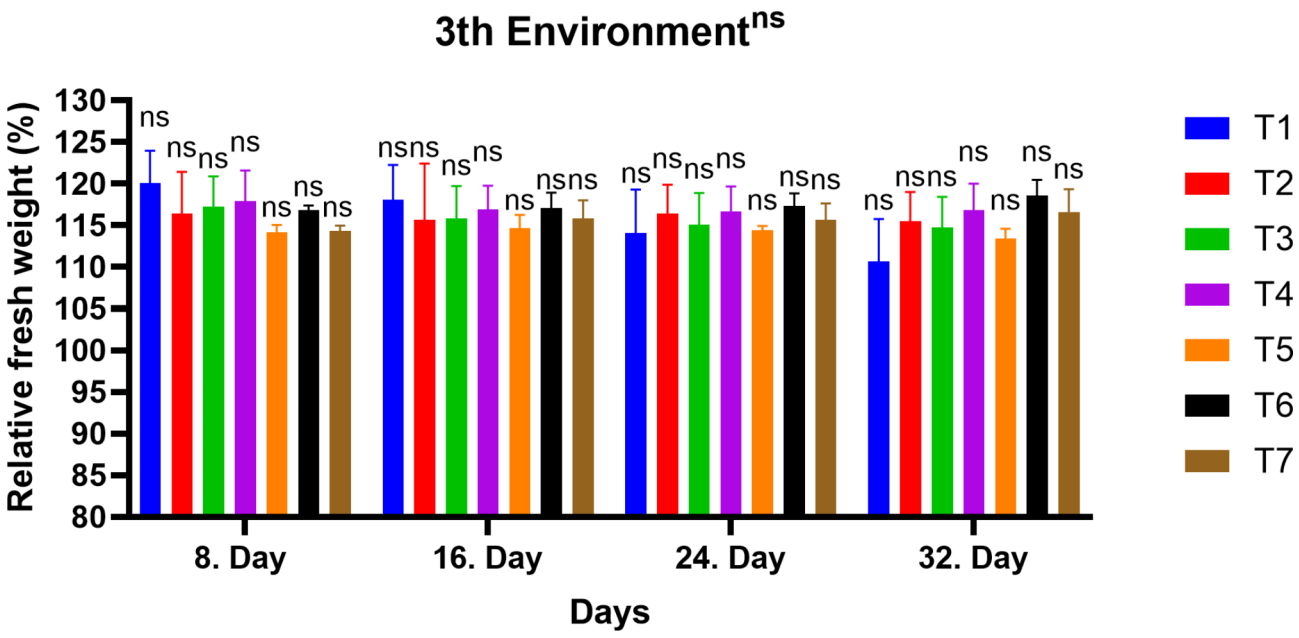

Fig. 7 Effect of different vase solutions on relative fresh weight of Gerbera flowers (%). *T1*: Distilled water, *T2*: 200 mg L^{-1} Streptomycin, *T3*: 400 mg L^{-1} Streptomycin, *T4*: 600 mg L^{-1} Streptomycin, *T5*: 200 mg L^{-1} Streptomycin + 50 g L^{-1} Sugar, *T6*: 400 mg/L Streptomycin + 50 g L^{-1} Sugar, *T7*: 600 mg L^{-1} Streptomycin + 50 g L^{-1} Sugar. (*3. Environment*: Cold storage at 2 ºC until vase life expires). Different letters do not indicate significant differences in each trait according to Duncan's test at $p > 0.05$. ns: non-significant

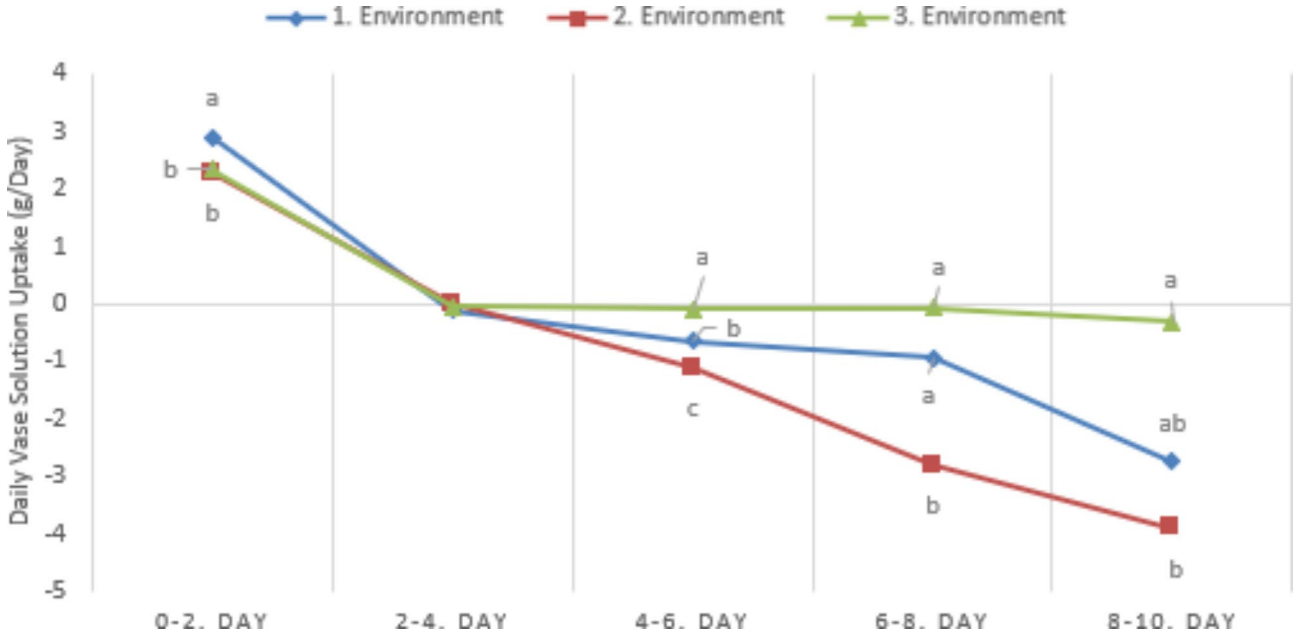

Fig. 8 Effect of different environments on daily vase solution uptake of Gerbera (*Gerbera jamesonii sp.*) (g day fresh $weight^{-1}$), *(1) Environment*: Room conditions, *(2) Environment*: Cold storage at 2 ºC after 48 h of room conditions, *(3) Environment*: Cold storage at 2 ºC until vase life expires)

Total vase solution uptake

Effects of different environments on total vase solution uptake values were found to be significant ($p < 0.05$). The greatest total vase solution uptake (189.04 g) was obtained from the 1st environment and the lowest total vase solution uptake (132.91 g) was obtained from 3rd environment (Fig. 9).

Effects of different vase solution treatments on total vase solution uptake were found to be significant in the 3rd environment ($p < 0.05$). In the 1st environment, the greatest total vase solution uptake (257.81 g) was seen in T7 environments, and the lowest value (132.46 g) was seen in T1 (control) environments. In the 2nd environment, the greatest total vase solution uptake

Table 2 Effects of different vase solutions on daily vase solution uptake of *Gerbera* flower (g / day fresh weight) (*1. Environment*: room conditions)

Treatment	0-2nd Day	2-4th Day	4-6th Day	6-8th Day	8-10th Day
T1	2.63 ab	-0.68 e	-0.79 abc	-0.96	-7.11
T2	2.75 ab	-0.22 cd	-0.94 bc	-1.02	-0.90
T3	3.14 ab	0.17 b	-0.74 abc	-1.05	-6.40
T4	3.13 ab	0.06 bc	-1.42 c	-1.54	-1.73
T5	2.13 b	-0.40 de	-0.34 ab	-0.44	-0.99
T6	3.19 ab	0.37 ab	-0.25 ab	-0.74	-0.84
T7	3.37 a	0.61 a	-0.01 a	-0.76	-1.23
Significance	*	*	*	ns	

Different letters indicate significant differences in each trait according to Duncan's test at $p < 0.05$. ns: non-significant

Table 3 Effects of different vase solutions on daily vase solution uptake of *Gerbera* flower (g day fresh weight^{-1}) (*2. Environment*: Cold storage at 2 °C after 48 h room conditions)

Treatment	0-2nd Day	2-4th Day	4-6th Day	6-8th Day	8-10th Day
T1	2.06 ab	-0.76 b	-1.24 abc	-4.97	-11.26 b
T2	2.17 ab	0.79 a	-2.49 c	-5.42	-5.03 ab
T3	1.88 b	-0.02 ab	-1.42 bc	-5.68	-0.62 a
T4	2.89 a	-0.13 ab	-2.06 c	-1.48	-6.77 ab
T5	2.46 ab	0.24 ab	-0.41 ab	-0.57	-1.05 a
T6	2.27 ab	0.33 ab	-0.14 ab	-0.79	-1.38 a
T7	2.19 ab	0.40 ab	-0.02 a	-0.67	-1.24 a
Significance	*	*	*	ns	*

Different letters indicate significant differences in each trait according to Duncan's test at $p < 0.05$. ns: non-significant

Table 4 Effects of different vase solutions on daily vase solution uptake of *Gerbera* flower (g day fresh weight^{-1}) (*3. Environment*: Cold storage at 2 °C until vase life expires)

Treatment0	2nd Day	2-4th Day	4-6th Day	6-8th Day 8	8-10th Day
T1	2.75 a	-0.27	-0.53	-0.47 d	-0.59
T2	2.23 ab	-0.05	-0.09	-0.14 c	-0.54
T3	2.48 ab	-0.20	-0.12	-0.06 bc	-0.11
T4	2.70 a	-0.13	-0.03	0.02 abc	-0.37
T5	1.91 b	-0.08	-0.02	-0.13 c	-0.46
T6	2.30 ab	-0.03	-0.03	0.18 a	-0.06
T7	2.02 ab	-0.23	-0.03	0.14 ab	-0.82
Significance	*	ns	ns	*	ns

Different letters indicate significant differences in each trait according to Duncan's test at $p < 0.05$. ns: non-significant

(210.55 g) was seen in T5 environments, and the lowest value (96.45 g) was seen in T1 environments. In the 3rd environment, the greatest total vase solution uptake (161.05 g) was seen in T3 environments, and the lowest value (97.53 g) was seen in T1 (control) environments. In terms of averages, the greatest total vase solution uptake

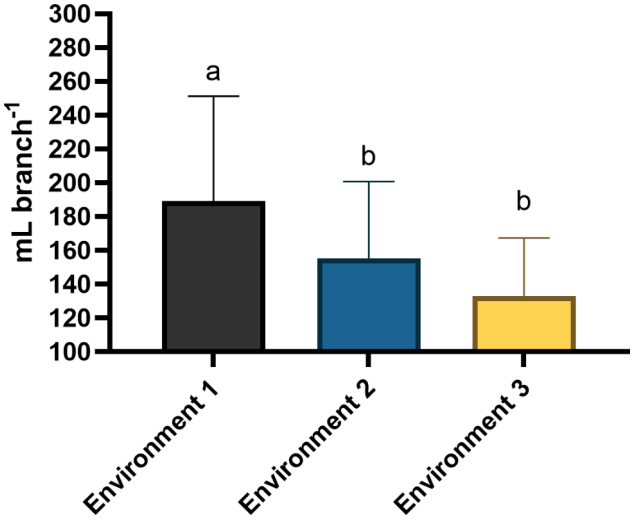

Fig. 9 Effects of different environments on total vase solution uptake of *Gerbera* flower (mL branch^{-1}), *(1) Environment*: Room conditions, *(2) Environment*: Cold storage at 2 °C after 48 h room conditions, *(3) Environment*: Cold storage at 2 °C until vase life expires

(194.74 g) was seen in T7 treatments, and the lowest value (108.81 g) was seen in T1 environments. As compared to T1 treatments, about 79% increase was seen in T7 treatments (Fig. 10).

Bacteria counts of vase solutions

In terms of the effects of different environments and vase solution treatments, it was seen that the 1st and 2nd environments had closer bacteria counts to each other. In the 1st environment, the lowest bacteria density (2.8×10^6 CFU mL^{-1}) was seen in T3 treatments, and the greatest bacteria density (2.7×10^8 CFU mL^{-1}) was seen in T6 treatments. The case was vice versa in the 2nd environment with the lowest density in T6 treatments and the greatest in T3 treatments. In the 3rd environment, there was decrease in bacteria densities. Colony development was not seen in T3, T4 and T6 environments, thus bacteria density was identified as 0. The greatest bacteria density was seen in T2 environments (Table 5). MALDITOF-MS technique was used to identify the bacteria cultures purified from nutrient agar media and present bacteria cultures were identified as *Pseudomonas extremorientalis* and *Serratia ficaria*.

Discussion

It was observed in present study that high streptomycin concentration, especially together with sugar, significantly increased vase life values of the flowers as compared to the control treatments. High antibacterial activity of streptomycin was also reported to be effective against gram-positive and gram-negative bacteria [26]. Streptomycin supplementations to vase solutions were thought to prevent bacterial congestion in plant stem and

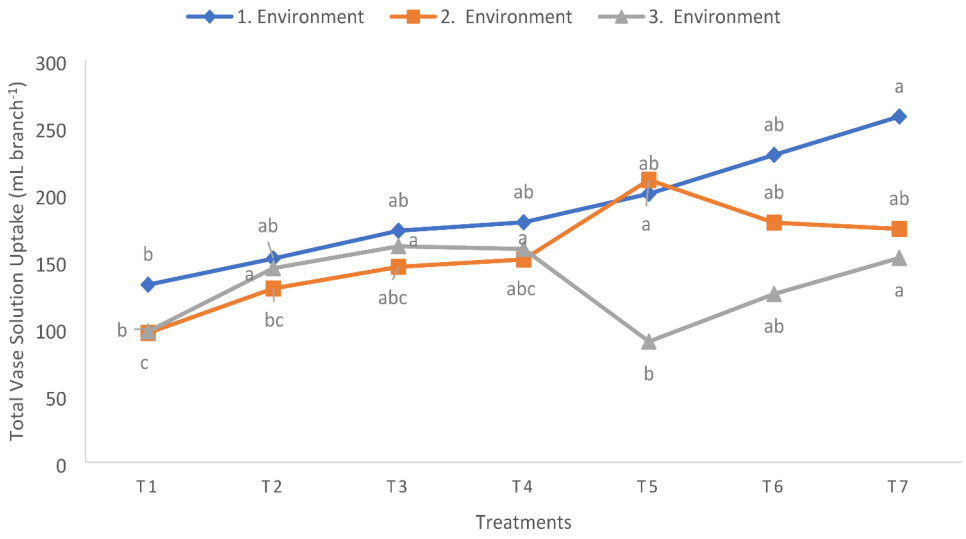

Fig. 10 Effects of different vase solutions on total vase solution uptake of *Gerbera* flower (mL branch^{-1}), *(1) Environment*: Room conditions, *(2) Environment*: Cold storage at 2 °C after 48 h room conditions, *(3) Environment*: Cold storage at 2 °C until vase life expires)

Table 5 Bacterial populations determined in treatments and environments

Treatments	Bacteria population (cfu mL^{-1})		
	Environment 1	Environment 2	Environment 3
T1	4.3×10^{7}	1.8×10^{8}	0.5×10^{6}
T2	2.2×10^{7}	8.4×10^{7}	4.9×10^{6}
T3	2.8×10^{6}	2.7×10^{8}	0
T4	6.7×10^{6}	7.8×10^{6}	0
T5	4.4×10^{6}	9.5×10^{7}	2.2×10^{6}
T6	2.7×10^{8}	4.9×10^{6}	0
T7	4.2×10^{7}	6.5×10^{6}	0

(1) Environment: Room conditions, *(2) Environment*: Cold storage at 2 °C after 48 h room conditions, *(3) Environment*: Cold storage at 2 °C until vase life expires

it was even more effective at higher doses. Al-Humaid [27] indicated that combination of 20% sugar and 250 ppm Streptomycin treatments increased vase life of 'Rose Supreme' and 'Nova Lux' varieties. Nair and Chung [28] reported that sucrose and antibacterial agents supplemented into vase solutions prolonged the vase life of cut flowers. Similar findings were also obtained in present study, and it was seen that streptomycin/sugar combinations with antibacterial characteristics prevented bacterial growth on the one hand and nourished the plant on the other hand. In addition, it was reported in other studies that biocides, especially used as anti-bacterial, prolonged the vase life of gardenia flowers [29]. Li et al. [30] reported that silver nanoparticles with antibacterial properties reduced bacteria density and consequently inhibited bacteria formation on stems of the cut gladiolus 'Eerde' variety. Damunupola and Joyce [31] and Faragher et al. [32] indicated that bactericides could have more than one effect and mechanism of action in the plant was very important. In this study, it was thought that Streptomycin had a positive effect on water uptake of Gerbera plant and this effect occurred because of its antibacterial effect on stem tips. In this way, it prevented bacterial growth and reduced xylem clogging. Longer vase life in the 3rd environment than the others resulted from this effect and the data in Figs. 2 and 3 confirm these results.

When the effects of environments on relative fresh weights were examined, it was observed that relative fresh weight losses increased in the 1st and 2nd environments as the number of days progressed, while this rate was quite low in the 3rd environment. Such differences were mainly attributed to excess of ethylene synthesis and resultant shedding, yellowing, fading, and darkening of flowers, leaves, and petals [33]. Such a case then shortened the vase life of flowers. Gerbera flowers are highly sensitive to ethylene and temperature values of the 3rd environment decreased this sensitivity through reduced respiration, thus prolonged the vase life. Increasing storage temperatures may increase respiration rates, thus shorten the vase life and result in weight losses. Early wilting of several cut flowers was also attributed to bacterial clogging in flower stems [33–35]. It was also reported that increased bacterial growth at basal root tips prevented nutrient flow from root tips to other parts of cut flowers or leaves [33, 34].

In terms of relative fresh weight change, based on the data taken in 2-day intervals for experimental treatments in the 1st and 2nd environments, it was observed that sugar-supplemented streptomycin treatments yielded better outcomes than both the control and only streptomycin treatments. Supplementation of streptomycin, an anti-bactericide, into vase solution prevented microbial growth and reduced bacterial density (Table 5). Especially combined streptomycin/sugar treatments increased the post-harvest quality of gerbera plants. Stockwell et al.

[37] reported that antibiotics and anti-bactericides better colonized in stem area and were more effective against pathogens that would form in the stem area and consequently prevented bacterial growth through antibacterial agents. It was also indicated that these substances were widely preferred because they prevented the clogging of xylem vessels and maintained water balance [19]. In the 3rd environment, the effect of vase solutions was more distinctive towards the end of the study as compared to the data measured in the first days, and streptomycin + sugar combinations yielded better outcomes at low storage temperatures.

When the effects of environments on daily vase solution uptakes were examined, it was seen that less losses were experienced in the 3rd environment as compared to the other environments. Such a case was mainly attributed to low storage temperatures. In studies using low temperature applications, it was reported that storage between 0 and 1 °C was the most effective method to preserve the quality of most cut flowers [38]. Similar results were also observed in plants stored at 2°C, the quality was preserved, and the least losses were experienced in daily vase solution uptake. Such losses were quite low especially in the 3rd environment as compared to the other environments. Inhibition of water transport along the stem caused water deficit in the plant and thus wilting, reducing water uptake rates [39–41]. It was determined that the 1st environment had more vase solution uptake than the 2nd and 3rd environments throughout the study. Such a case was primarily attributed to different treatments and temperature regimes. Since the respiration rate was higher under the 1st environment room conditions and the temperature was higher than the 3rd environment, both the plants easily benefited from the vase solution and the evaporation was higher in the 1st environment than the 3rd environment. It was reported for cut roses that low temperature storage resulted in 8 times less ethylene synthesis than the normal conditions [42]. It was reported in a study conducted on carnations that storage at 2°C slowed down the vital activities of the plants and consequently slowed down the vase solution uptake [43]. In terms of the effects of experimental treatments on total vase solution uptake, the best results were obtained from combined anti-bactericide streptomycin + sugar treatments, combined treatments directly affected the total vase solution uptake by preventing the clogging of xylem.

Conclusion

In this study, it was determined that Streptomycin yielded the best outcomes for all parameters, especially when it was combined with sugar and increased the vase life as compared to the control. As compared to the control treatments, with streptomycin treatments, the greatest increase in vase life was observed in T7 (600 ppm Streptomycin + 5% Sugar) treatments of the 1st environment (67.5%) (8.22–13.77 days), in T5 (200 ppm Streptomycin + 5% Sugar) treatments of the 2nd environment (117.34%) (7.67–16.67 days) and in T7 (600 ppm Streptomycin + 5% Sugar) treatments of the 3rd environment (62.29%) ((45.29–73.5 days). When the bacterial density of the environments was examined, it was observed that the bacterial densities of the 1st and 2nd environments were similar, but less in the 3rd environment. Especially in streptomycin treatments, no colony development was observed in nutrient medium, thus the density was given as 0. Therefore, combined streptomycin + sugar treatments can be used as an alternative commercial cut flower preservative solution to extend the vase life of cut flowers and improve post-harvest quality.

Abbreviations

STS	Silver Thiosulfate
RFW	Relative Fresh Weight
DVSU	Daily Vase Solution Uptake
WSt-1	Previous Day Weight of Vase Solution
WSt	Weight of Vase Solution on Day t (2, 4, 6, etc.)
Wt	Stem weight at day t (2, 4, 6, etc.)
Wt0	Stem weight at day 0
TVSU	Total Vase Solution Uptake
NA	Nutrient Agar
NaCl	Sodium Chloride

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Author contributions

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