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Effect of calcium chloride and floral preservatives in the vase life of gerbera cut flower

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ABSTRACT

Postharvest loss of cut flower at all the stakeholders in Nepal before reaching consumer is about 20-25% in Nepal. The major problem in gerbera for its vase life is stem or scape bending. This study was aimed to assess the effect of calcium chloride and different floral preservatives in the vase life and to evaluate the quality of different varieties of gerbera cut flower. The study was conducted in a completely randomized design in the controlled lab of Central Agricultural Laboratory located at Hariharbhawan, Lalitpur at 17±2 ˚C temperature, 55 ± 2% relative humidity (RH) and 100 lux light. The study revealed that among two varieties, Rosalin, a light pink variety of gerbera was found to be better with prolonged vase life. Rosalin showed the longest vase life (14.05 days) with higher solution uptake (13.97 mL) and recorded minimum stem bending (43.8˚) on 15th day of vase life. Among ten different vase solutions, 4% sucrose + 1% calcium chloride (18.25 days), 4% sucrose + 0.5% calcium chloride (16.58 days) and 0.5% calcium chloride (16.25 days) were found the most effective vase solutions to prolong the vase life of gerbera cut flower as compared to control (7.67 days). Vase life solution of 4% sucrose + 1% calcium chloride is a potential commercial preservative solution to improve the keeping quality and vase life of cut gerbera. To conclude, calcium treatment along with a carbohydrate in a vase solution improves the vase life of gerbera cut flower.

Keywords: Calcium chloride, calcium content, gerbera, stem bending, vase life

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INTRODUCTION

Floriculture is one of the emerging sub sectors in Nepalese agriculture (FAN 2010). In Nepal, floriculture business has grown tremendously. In contrary, due to covid-19, it has declined from an annual turnover of about NRs 2250 million in 2019 to NRs 2153.27 million at present (FAN 2021). Gerbera (*Gerbera jamesonii* Bolus ex Hook.f.) is one of the top ten cut flowers in the world. It occupies fourth position after rose, chrysanthemum and tulip (Choudhary and Prasad 2000). It is commonly known as "Transval daisy", "Barbeton daisy" or “African daisy” and belongs to family Asteraceae (Emongor 2004). Gerbera is found in different colors, and it is widely used in many floral arrangement, bouquet and dry flower crafts in the world (Hema et al 2018). Gerbera grows well when cultivated under protected condition. It has become more popular because of its demand in local as well as in foreign market (Chobe et al 2010).

The most important quality criteria for gerbera cut flowers are non-defective petals, appropriate stem length, stem toughness and stem straightness. Scape bending is one of the main postharvest disorders of gerbera cut flower that induces shortening of vase life (Perik et al 2012). Stem or scape hollowness is another main reason for scape bending which arises due to poor lignification of tissues. The other factor which induces the stem bending during vase life was found to be low water uptake in cut gerberas caused by bacterial blockage. But recent studies show that, stem bending is associated with the loss of mechanical strength (Cheng et al 2020). Mechanical properties of plant tissues are affected by cell wall components and phenolic derivatives. Stem bending might be related to lignin level and lignin synthesis related genes that are down regulated in flower stem during vase life (Cheng et al 2020). Calcium treatment in cut flowers enhances the mechanical strength of the inflorescence stems by increasing the lignin accumulation (Zhao et al 2019). Postharvest life of cut flower is very sensitive as flowers are highly perishable in nature. Postharvest loss of cut flowers across all stakeholders in Nepal before reaching consumer is about 20-25% but sometimes loss of a single crop at grower’s level could be as high as 30% (Gaire et al 2010).
This study was aimed on postharvest treatment of calcium chloride along with floral preservatives in prolonging the vase life of gerbera cut flower. The major cause of lower vase life in gerbera cut flower is stem or scape bending. Stem hollowness is another reason causing lower vase life of gerbera triggered by high humidity and high temperature (Pun and Ichimura 2016). In this case anti-microbial agent alone in the vase solution is not able to improve vase life of cut flower gerbera. Addition of calcium chloride in vase solution along with floral preservatives is one of the best solutions to increase the lignification of tissue and its vase life. Resolving this problem could benefit growers, wholesalers, retailers and the consumers.

MATERIALS AND METHODS

The study was conducted at the laboratory of Central Agricultural Laboratory, Hariharbhawan, Lalitpur, Nepal. Two cultivars of gerbera cut flower ‘Rosalin’ and ‘Carambole’ were used for this study which were grown in standard UV stabilized PE plastic greenhouse conditions from the farm Sunrise Agritech, in a semi-high-tech greenhouse located at Dadhikot, Bhaktapur, Nepal. Flowers were placed in clean water immediately after harvest and flower heads were wrapped with plastic to minimize the injury during transportation. Gerbera cut flowers were brought carefully to the laboratory within 2 hours of harvest without causing any damage. After checking and rejecting abnormal, diseased and damaged flower, selected cut flowers were kept in ten different vase solutions by slant cutting at base. Fifty centimeter stem length was cut to 30 cm. The experiment was conducted during winter season. The experiment was laid out in two factorial completely randomized design (CRD) with 10 treatments replicated 3 times. The treatments were 1. 4% Sucrose, 2. 4% Sucrose + 20 ppm NaOCl, 3. 20 ppm NaOCl, 4. 4% Sucrose + 0.5% $CaCl_2$, 5. 4% Sucrose + 1% $CaCl_2$, 6. 4% Sucrose + 1.5% $CaCl_2$, 7. 0.5% $CaCl_2$, 8. 1% $CaCl_2$, 9. 1.5% $CaCl_2$ and 10. distilled water (Control). Gerbera cut flowers were placed in 500 mL conical flask containing ten types of 250 mL vase solutions. Two cut flowers in one flask were placed for vase life study. The top of conical flask was wrapped with aluminum foil to prevent from evaporation loss after keeping flowers in vase solution. For vase life study, flowers were kept in a controlled room having average daily temperature at 17˚C±2˚C temperature and 55±2% relative humidity and 100 lux light (on an average) from 6 a.m. to 6 p.m. The light was measured by Digital lux meter (Voltcraft BL 10 L), Voltcraft company.

Vase life (days)
Vase life was evaluated daily up to vase life termination stage.

Solution uptake (mL)
After placing the stem of the flower in the conical flask containing different vase solutions, the level of solution of flask was marked. Solution uptake was measured in two days interval of vase life with the help of 5, 2 and 1 mL syringes separately for different vase solutions. The added volume of the solution at the marked point after 2 days interval was considered as the solution uptake of the flower.

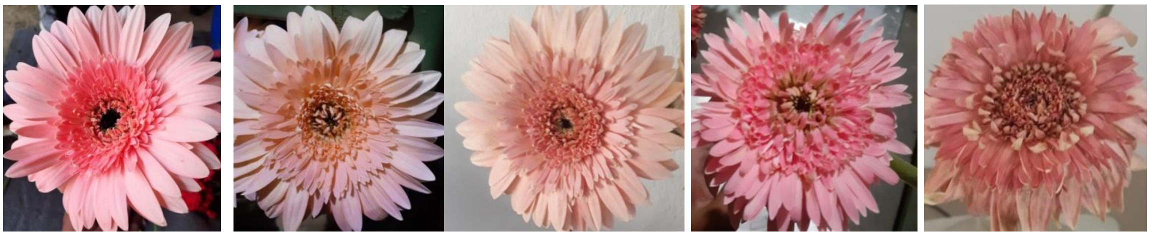
Stem diameter (mm)
Stem diameter was measured using vernier caliper. Stem diameter was measured at the time of stem placing in vase solution and later at the five days interval.

Stem bending (degree)
Stem bending was measured at 3 days interval using a protractor and was expressed with respect to the angle on day 0 of vase life. Stem bending was determined by assessing the accompanying change in the position of the floral head.

Vase life evaluation
Flower quality was observed daily in the observation room. On the visual basis, vase life evaluation was scored as 5-1 (Figure 1, 2). Grade 5 was considered as the best quality of flower whereas grade 1 as the vase life termination stage (Acharya et al 2010). Stem of the flower was examined visually for the sign of rotting. Vase life was recorded as the time period when more than one third of the outer petals of inflorescence started to be brown or wilted.

5 4 3 2 1

Figure 1. Vase life evaluation of cv. Carambole



5 4 3 2 1

Figure 2. Vase life evaluation of cv. Rosalin

Data collection and analysis

Data were collected daily for some parameters like vase life (days), vase life evaluation. The collected data were transferred to MS- Excel and statistically analysed with the help of GenStat 7th edition. Mean separation was done by DMRT at 5% level of significance (Gomez and Gomez 1984).

RESULTS

Vase life (days)

The vase life of gerbera cut flower kept in different vase solutions is presented in Table 1. Among the ten different vase solutions, the longest vase life (18.25 days) was found in 4% sucrose + 1% $CaCl_2$ while the lowest vase life was observed in control (7.67 days). Also, the longest vase life of flower (14.05 days) was found in Rosalin whereas the shortest vase life (12.32 days) was found in Carambole (Table 1).

Table 1. Variation in the vase life of gerbera cut flower kept at different vase solutions

Treatments (Factor A)	**Vase life (days)**
4% Sucrose	$12.00^{cd} \pm 1.34$
4% Sucrose+ 20 ppm NaOCl	$13.00^{c} \pm 1.20$
20 ppm NaOCl	$12.17^{cd} \pm 0.83$
4% Sucrose+ 0.5% $CaCl_2$	$16.58^{ab} \pm 0.75$
4% sucrose+ 1% $CaCl_2$	$18.25^{a} \pm 0.47$
4% Sucrose+ 1.5% $CaCl_2$	$15.25^{b} \pm 0.58$
0.5% $CaCl_2$	$16.25^{ab} \pm 0.40$
1% $CaCl_2$	$10.67^{cd} \pm 1.11$
1.5% $CaCl_2$	$10.00^{d} \pm 0.82$
Distilled water (control)	$7.67^{e \pm}$ 0.49
Grand mean	13.18
LSD (0.05)	2.182
F-test	**
Cultivars (Factor B)	**Vase life (days)**
Rosalin	$14.05^{a} \pm 0.69$
Carambole	$12.32^{b} \pm 0.63$
Grand mean	13.18
LSD (0.05)	0.976
F-test	**
Varieties × vase solutions	ns
CV%	14.2%

ns; non-significant, *P<0.05, **P<0.01, CV; Coefficient of variation, LSD; Least significant difference, ±; standard error of mean, means separation in column followed by the same letters are not significantly different at P<0.05

Solution uptake (mL)

Solution uptake in gerbera cut flowers increased in earlier days. After few days, solution uptake gradually declined. Among different vase solutions, maximum uptake of solution (30 mL) on 3rd day was observed with the treatment containing 4% sucrose + 20 ppm sodium hypochlorite, while on 6th day of vase life, the highest solution uptake (12.82 mL) was observed in the flowers kept in the solution 4% sucrose + 1% $CaCl_2$. Likewise, the lowest solution uptake was found in the flower stems kept in Control (6.13 mL) as shown in (Table 2).

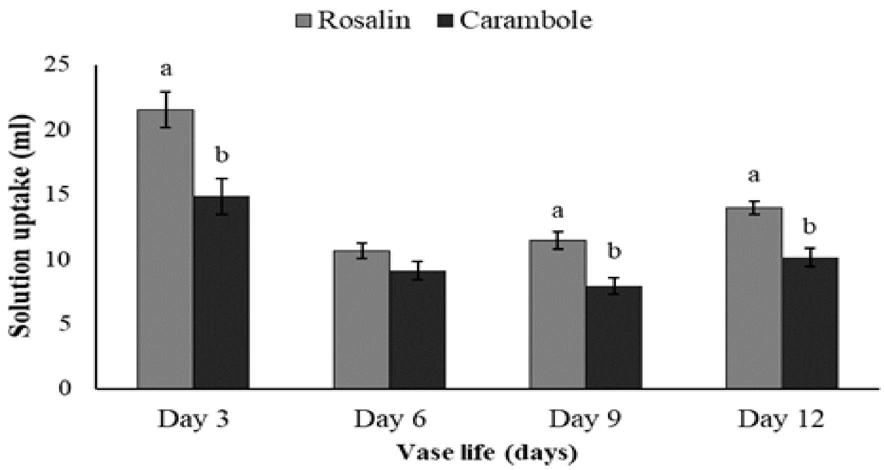


Figure 3. Response of varieties on vase solution uptake treated with different vase solution. Vertical bars in the column represents mean ± SE. Different letters above the column indicate that mean values were significantly different by DMRT at P<0.05 on the same sampling date

Table 2. Variation in vase solution uptake by gerbera cut flower at different dates

	Solution Uptake (mL)			
Treatments	**Day 3**	**Day 6**	**Day 9**	**Day 12**
4% Sucrose	14.60^{c}±1.69	8.70^{bcd}±0.96	7.22^{de}±1.17	9.73^{de}±1.29
4% Sucrose+ 20ppm NaOCl	30.00^{a}±3.39	12.27^{ab}±2.11	10.55^{bcd}±2.09	13.68^{abc}±1.34
20 ppm NaOCl	11.83^{c}±2.29	9.15^{abcd}±1.28	9.42^{bcd}±2.11	9.97^{de}±1.65
4% Sucrose+ 0.5% $CaCl_2$	26.05^{ab}±3.84	12.35^{ab}±0.80	10.87^{bc}±1.26	14.52^{ab}±0.57
4% sucrose+ 1% $CaCl_2$	15.32^{c}±3.19	12.82^{a}±0.53	14.43^{a}±1.46	16.37^{a}±1.06
4% Sucrose+ 1.5% $CaCl_2$	13.95^{c}±2.46	10.25^{abc}±1.52	11.93^{ab}±1.22	12.52^{bcd}±1.51
0.5% $CaCl_2$	16.13^{c}±2.03	12.65^{a}±0.88	10.27^{bcd}±1.27	13.70^{abc}±1.34
1% $CaCl_2$	23.43^{c}±2.11	6.63^{cd}±0.87	8.72^{bcde}±0.91	11.98^{bcd}±1.19
1.5% $CaCl_2$	15.13^{c}±2.51	7.92^{cd}±1.14	7.90^{cde}±1.22	11.15^{cd}±1.65
Distilled water (control)	15.40^{c}±2.19	6.13^{d}±0.88	5.63^{e}±0.57	7.03^{e}±0.85
Grand mean	18.19	9.89	9.69	12.06
LSD (0.05)	6.102	3.490	2.996	1.395
F-Test	**	**	**	**
CV%	28.8%	30.3%	26.5%	20%

*P<0.05, **P<0.01, CV; Coefficient of variation, LSD; Least significant difference, ±; standard error of mean, means separation in column followed by the same letters are not significantly different at P<0.05

The highest vase solution uptake (21.53 mL and 13.97 mL) was observed in cv. Rosalin whereas the lowest uptake (14.84 mL and 10.16 mL) was observed in cv. Carambole on day 3 and day 12 respectively (Figure 3).

Stem diameter (mm)

There was no effect of vase solutions on the stem diameter on the 1st and 5th day whereas on the 10th day of vase life, the highest stem diameter (5.43 mm) was recorded in flower placed in vase solution containing 4% sucrose + 1% $CaCl_2$. The lowest stem diameter (4.49 mm) was observed in the vase solution containing no floral preservatives i.e. control (Table 3).

Table 3. Variation on stem diameter of gerbera cut flower kept in different vase solutions

	Stem diameter (mm)						
Treatments	**Day 1**	**Day 5**	**Change (%)**	**Day 10**	**Change (%)**	**Day 15**	**Change (%)**
4% Sucrose	5.61±0.21	5.08±0.23	-9.44	4.71^{cd}±0.26	-15.93	4.48^{cd}±0.25	-20.10
4% Sucrose+ 20 ppm NaOCl	6.02±0.25	5.65±0.18	-6.06	5.34^{ab}±0.22	-11.35	5.04^{ab}±0.23	-16.24
20 ppm NaOCl	5.60±0.20	5.08±0.24	-9.26	4.80^{bcd}±0.28	-14.32	4.64^{bcd}±0.28	-17.15
4% Sucrose+ 0.5% $CaCl_2$	5.88±0.18	5.37±0.20	-8.67	5.10^{abc}±0.21	-13.35	4.93^{abc}±0.21	-16.21
4% sucrose+ 1% $CaCl_2$	5.76±0.25	5.53±0.21	-3.92	5.44^{a}±0.20	-5.63	5.23^{a}±0.15	-9.20
4% Sucrose+ 1.5% $CaCl_2$	5.69±0.11	5.35±0.17	-5.90	5.18^{abc}±0.15	-8.93	4.99^{ab}±0.15	-12.38
0.5% $CaCl_2$	5.64±0.13	5.34±0.16	-5.32	5.17^{abc}±0.18	-8.30	5.06^{ab}±0.17	-10.35
1% $CaCl_2$	5.49±0.18	5.20±0.19	-5.15	4.89^{bcd}±0.17	-10.79	4.67^{bcd}±0.17	-14.83
1.5% $CaCl_2$	5.53±0.15	5.16±0.18	-6.76	4.88^{cd}±0.20	-11.75	4.71^{bcd}±0.17	-14.95
Distilled water (control)	5.52±0.27	5.02±0.32	-9.12	4.49^{d}±0.27	-18.71	4.29^{d}±0.25	-22.21
Grand mean	5.673	5.279		4.999		4.803	
LSD	0.4170	0.4499		0.4245		0.4106	
F-test	**	**		**		**	
CV%	6.3%	7.3%		7.3%		7.3%	
Varieties	**Day 1**	**Day 5**		**Day 10**		**Day 15**	
Rosalin	5.89^{a}±0.08	5.51^{a}±0.08	-6.39	5.28^{a}±0.08	-10.33	5.05^{a}±0.08	-14.13
Carambole	5.46^{b}±0.09	5.05^{b}±0.10	-7.55	4.72^{b}±0.11	-13.54	4.55^{b}±0.11	-16.65
Grand mean	5.673	5.279		4.999		4.803	
LSD (0.05)	0.1865	0.2012		0.1898		0.1836	
F-test	**	**		**		**	
CV%	6.3%	7.3%		7.3%		7.3%	
Vase solutions × varieties	ns	ns		ns		ns	

ns; non significant, *P<0.5, **P<0.01, CV; Coefficient of variation, LSD; Least significant difference, ±; standard error of mean, means separation in column followed by the same letters are not significantly different at P<0.05

In cv. Rosalin, the lowest reduction on stem diameter was observed with 6.39%, 10.33% and 14.11% in comparison to 1st day. The highest reduction on stem diameter was observed in cv. Carambole, with 7.54%, 13.54% and 16.64% on 5th day, 10th day and 15th day of vase life respectively. The lowest percentage reduction on stem diameter was observed in flower placed in 4% sucrose + 1% $CaCl_2$, with 3.92%, 5.63% and 9.20% on day 5, day 10 and day 15 of vase life respectively (Table 3).

Stem bending (degrees)

Stem bent gradually during entire vase life days. The lowest stem bending (7.50˚, 11.00˚, 14.2˚ and 18.3˚) was observed in the treatment combination of 4% sucrose + 1% $CaCl_2$ on 4th, 8th, 12th and 16th day of vase life respectively, while the highest bending (27.6˚, 42.8˚, 61.3˚ and 85.1˚) was obtained in the treatment control (T10) on 4th, 8th, 12th and 16th day of vase lives respectively as shown in the Table 4.

Table 4. Influence of varieties and vase solution on the stem bending of gerbera

	Stem bending (degree)				
Vase solutions	**Day 1**	**Day 4**	**Day 8**	**Day 12**	**Day 16**
4% Sucrose	†6.8±1.37	16.3^{bcd}±3.03	24.8^{b}±4.12	39.0^{b}±7.21	64.5^{b}±7.77
4% Sucrose+ 20 ppm NaOCl	8.5±1.93	13.0^{cdef}±1.73	18.3^{cd}±2.19	26.0^{cd}±4.18	39.7^{c}±5.62
20 ppm NaOCl	8.2±1.37	16.9^{bc}±1.90	24.8^{b}±3.38	38.3^{b}±7.81	64.3^{d}±6.56
4% Sucrose+ 0.5% $CaCl_2$	6.8±1.30	9.3^{fg}±1.40	13.3^{de}±1.80	18.3^{de}±2.21	23.0^{d}±2.26
4% sucrose+ 1% $CaCl_2$	5.8±0.83	7.5^{g}±1.24	11.0^{e}±1.02	14.3^{e}±1.26	18.3^{d}±1.67
4% Sucrose+ 1.5% $CaCl_2$	7.1±1.57	10.3^{efg}±1.65	15.1^{de}±1.59	20.6^{de}±1.66	27.4^{d}±2.28
0.5% $CaCl_2$	10.0±2.15	11.8^{defg}±1.53	15.3^{de}±1.39	19.7^{de}±1.42	26.8^{d}±1.68
1% $CaCl_2$	8.2±1.20	18.1^{b}±2.56	23.9^{bc}±2.40	35.2^{bc}±5.33	54.8^{b}±5.95
1.5% $CaCl_2$	9.2±1.57	15.0^{bcde}±1.74	21.7^{bc}±2.70	35.4^{bc}±4.50	60.7^{b}±6.62
Distilled water (control)	8.3±1.31	27.6^{a}±4.06	42.8^{a}±4.78	61.3^{a}±5.40	85.1^{a}±3.02
Grand mean	7.88	14.59	21.07	30.8	46.5
LSD	3.609	4.303	5.890	10.21	10.55
F-test	NS	***	***	***	***
CV%	39.3%	25.3%	24%	28.4%	19.5%
Varieties					
Rosalin	†7.5±0.64	13.9±1.53	19.7^{b}±1.86	27.4^{b}±2.47	43.8^{b}±4.23
Carambole	8.3±0.72	15.3±1.24	22.5^{a}±2.10	34.2^{a}±3.65	49.2^{a}±4.62
Grand mean	7.88	14.59	21.07	30.8	46.5
LSD (0.05)	1.614	1.924	2.634	4.57	4.72
F-test	ns	ns	*	**	*
CV%	39.3%	25.3%	24%	28.4%	19.5%
Vase solutions × variety	ns	ns	ns	ns	ns

*P<0.5, **P<0.01, CV; Coefficient of variation, LSD; Least significant difference, ±; standard error of mean, means separation in column followed by the same letters are not significantly different at P<0.05, ns; non significant

The highest bending (22.43˚) was observed in cv. Carambole and the lowest stem bending (19.72˚) was observed in cv. Rosalin at 8th day. Similarly, at 12th and 16th day, the highest bending (34.2˚ and 49.2˚) was observed in cv. Carambole and the lowest bending (27.4˚ and 43.8˚) was observed in cv. Rosalin.

Calcium content

Calcium content was determined in scape of cut gerbera kept on seven treatments out of ten treatments. The calcium chloride treated cut flowers were taken for the examination of calcium content which was compared with the control. Among the seven treated vase solution, the highest calcium content (1.585 mg) was observed in 1.5% $CaCl_2$ and the lowest 0.217 mg with control (Distilled water) (Table 5). Calcium content in the scape was determined after termination of flower and cv. Rosalin contained higher calcium content (1.123 mg) as compared to cv. Carambole (0.916 mg) (Table 5).

Table 5. Calcium content in the gerbera cut flower kept in different vase solutions

Treatments	Calcium content (mg/g)
Factor A (vase solution)	
4% Sucrose+ 0.5% $CaCl_2$	$0.78^{e}\pm0.05$
4% Sucrose+ 1% $CaCl_2$	$1.04^{cd}\pm0.07$
4% Sucrose+ 1.5% $CaCl_2$	$1.00^{d}\pm0.05$
0.5% $CaCl_2$	$1.18^{bc}\pm0.07$
1% $CaCl_2$	$1.34^{b}\pm0.08$
1.5% $CaCl_2$	$1.59^{a}\pm0.13$
Distilled water (control)	$0.34^{f}\pm0.05$
Grand mean	1.02
LSD (0.05)	0.16
F-test	**
Varieties (Factor B)	
Rosalin	$1.15^{a}\pm0.08$
Carambole	$0.92^{b}\pm0.06$
Grand mean	1.02
LSD (0.05)	0.08
F-test	**
F-test (Varieties × vase solution)	ns
CV	13.7%

*P<0.5, **P<0.01, CV; Coefficient of variation, LSD; Least significant difference, ±; standard error of mean, means separation in column followed by the same letters are not significantly different at P<0.05, ns; non significant

DISCUSSION

Vase life of flower is very crucial in determining the quality of cut flower. Chemicals used in vase solutions play a significant role in increasing vase life. The present study revealed that calcium treated gerbera cut flowers recorded highest vase life. Halevy and Mayak (1981) found out that calcium treated cut flowers showed increased ATPase activity which might be owing to increased longevity of cut flower. Similarly, longer vase life was observed in cv. Rosalin as compared to cv. Carambole because cv. Rosalin had lower stem bending incidence than Carambole. Furthermore, the delay of stem bending is associated with higher content of calcium ions. Thus, longer vase life of Rosalin is associated with higher content of calcium ions. The additional application of calcium chloride in both the varieties being effective in increasing the vase life proves the importance of calcium ions in delaying stem bending and thereby increasing the vase life. Gerasopoulos and Chebli (1999) support the present study from their findings as it depicts that calcium accumulation in plants facilitates cross linking of pectin polymers in the middle lamella to form a cell wall network that increases mechanical strength that delays the stem bending. The role of intra and intercellular calcium on cell metabolism change is attributed to its effect on the membrane structure and function and cell walls (Ferguson and Drobak 1988). Similar findings have been reported by Perik et al (2014), which explains that calcium ion maintains cell wall rigidity which binds the pectin molecules increasing the cell wall stiffness which also has its role in the synthesis of pectin located in cell wall of xylem vessels which facilitates the water translocation in stem and inhibits stem bending. Calcium treated cut flowers showed increased thickening of sclerenchyma cell walls and main wall constitutive component lignin. In the study conducted by Zhao et al (2019), both *NAC* and *MYB* transcription factors were differentially expressed in response to nano-$CaCO_3$ treatment in herbaceous peony stems. Their higher expression levels under nano-$CaCO_3$ treatment were high which indicated that calcium-binding proteins upregulated *NAC* and *MYB* transcription factors thereby inducing secondary cell wall biosynthesis. Sucrose also induces the accumulation of monolignol substrate phenylalanine that enhances the monolignol biosynthesis. These processes ultimately resulted in an increased lignin accumulation which led to an increased mechanical strength in the stems of herbaceous peony.

Few studies have explored the effect of calcium chloride application on extending the vase life of cut flowers. The present study revealed that combination of 4% sucrose + 1% $CaCl_2$ positively influence the vase life of gerbera cut flower along with delaying stem bending. Calcium chloride acts as antibacterial agent (Wagh 2015) as well as provide mechanical rigidity to stem owing to less damage of stem (Perik et al 2014). This might be the reason in less reduction in diameter in treatment containing 4% sucrose + 1% $CaCl_2$ was observed. Reduction in stem diameter is very much prominent with vase lives because the hollowness inside the stem goes on increasing with the vase life due to breakdown of bundles and cortical parenchyma cell (Cheng et al 2020). Perik et al (2014) also reported that when only chlorine containing preservatives are used in vase solution it will make the stem lighter thus when 25 or 50 mM $CaCl_2$ is used along with the other treatment then it somehow showed the stem rigidity due to Ca^{++} ions. Similar, results were reported by De Witte et al (2014) and Zhao et al (2019).

Sucrose maintains the supply of substrates for respiration, water balance and turgidity whereas $CaCl_2$ at various concentrations acts as biocide inhibiting microbial population that might have resulted in higher solution uptake (Soad et al 2011). Similar result was obtained by Combrink (2017) explaining higher water uptake might be due to the Ca strengthening the stems. Perik et al (2014) reported similar result in delaying stem bending in gerbera cut flower with an addition of $CaCl_2$ in the treatment. According to Brummell (2006), delay of stem bending might be due to calcium ion's role in coupling of pectin molecules resulting in more cell wall stiffness. The positive effect of sucrose was also observed when combined with antimicrobial compound delaying stem bending in cut flower gerbera (Steinitz 1983). Similar, result was obtained in research conducted by Muraleedharan et al (2019) which explained that sucrose creates osmotic pressure inside the cells allowing water to enter inside the cells which will make a stem rigid and upright.

High scape calcium content might be due to the easier penetration and higher calcium absorption capacity of internal scape tissue and less absorption of calcium might be due to the scape cavity inside the scape of gerbera. Also, the tissue calcium content affects all the developmental stages during the plant growth (Ferguson and Drobak 1988). Although, higher calcium content was observed in the scape treated with 1.5% $CaCl_2$, it did not show any additional increase in vase life or delayed stem bending in gerbera. This result is in line with the research reported by Gerasopoulos and Chebli (1999), increasing calcium chloride treatment above 1.0% resulted in higher calcium content but with no additional increase in flower longevity or decreases in vase life due to calcium toxicity (Gerasopoulos and Chebli 1999, Geshnizjany et al 2014). This might be the reason that even with the high scape calcium content in the cut flowers treated with 1.5% $CaCl_2$ (T9) and 1.0% $CaCl_2$ (T8) singly did not positively influenced the vase life of both gerbera cultivars Rosalin and Carambole.

CONCLUSION

The study concluded that gerbera cut flowers kept in vase solution containing 4% Sucrose + 1% $CaCl_2$ (T5) showed the highest vase life. However, among two cultivars of gerbera cut flower, Rosalin was found superior in vase life, delaying stem bending, solution uptake, calcium content and stem diameter as compared to cv. Carambole. The difference is more likely because of higher calcium content in cv. Rosalin which delayed stem bending and reduction in stem diameter resulting lower vase life. For commercial use, vase solution containing 4% sucrose + 1% $CaCl_2$ (T5) can be recommended to growers, wholesalers and retailers for prolonging the vase life of gerbera cut flower. Similarly, the preservatives are economically cheap and easily available in the market.

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Author contributions

S Timalsina, PR Poudel, AK Acharya, R Pathak, UK Pun conceived and designed the experiments; S Timalsina performed the experiments, analyzed and interpreted the data and wrote the draft of the paper; PR Poudel, A Acharya and UK Pun reviewed and corrected the draft manuscript.

Conflicts of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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