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Water Relations and Post Harvest Life of Cut Gerbera as Affected by Ethylene Inhibitors

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ABSTRACT

The present investigation "Variability and post-harvest studies in gerbera (*Gerbera jamesonii* L.) in a naturally ventilated polyhouse" was carried out at the College of Horticulture, Rajendranagar, Hyderabad. The best gerbera genotype Goliath with the longest field life of flower scapes was used for post-harvest studies by using ethylene inhibitors. Addition of ethylene inhibitors to the holding solutions viz., Silver thiosulfate, Benzyl Adenine and Salicylic Acid at different concentrations were tested on water relations of the genotype cut flower. Data on fresh weight of flower, Water Uptake, Total loss of water, Water balance, Flower stalk bending, Flower diameter and Vase life were recorded. STS found as the best treatment in suppressing the microbial growth in the vase solution there by increased the water relations in the floral tissue and thereby improved post-harvest quality of cut gerbera. STS increased the sucrose content of vase solution which in turn helped in increasing water uptake and reduction of transpiration loss by reducing the opening of stomata thus maintaining turgidity of flowers. Also, adding STS to the holding solution increased the concentrations of glucose and fructose in florets and this data indicated that STS may improve sucrose uptake and its subsequent hydrolysis. Among the ethylene inhibitors, Silver thiosulfate 0.2 mM along with sucrose 4% recorded highest for almost all the quality parameters studied and resulted in higher vase life of (10.67 days), lower scape bending (5.39 degrees) and maximum flower diameter (9.62 cm) in cut gerbera cv Goliath compared to control. In addition, silver ion available in the silver thiosulfate had bactericidal property and reduced the frequency of bent necks and improved the vase life of cut gerbera.

Keywords Benzyl adenine, Flower stalk bending, Gerbera, Salicylic acid, Silver thiosulfate.

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INTRODUCTION

Gerbera is an ornamental flower plant grown throughout the world and known as African daisy or Transvaal daisy. The gerbera plant with tropical origin and belongs to composite family. Gerbera flowers occupies a prominent position amongst the elite group of top ten cut flowers of the international flower markets. Adding the anti-ethylene compounds to holding solutions can effectively protect flowers against exogenous ethylene. Ethylene gas can shorten the life of many floral crops, causing flower and bud drop, premature wilting, and flower discoloration. Slightly acidic sucrose solution plays an important role to extend the vase life providing the food for cut flowers and by stopping the growing of microorganisms on solution (Mehraj *et al*. 2013a).

Silver thiosulfate (STS) is effective in extending the vase life of cut flowers is related to suppression in the induction of autocatalytic production by inhibition of ethylene action. Cytokinins are natural anti-senescence hormones by preventing degradation of various macromolecules and their declining levels account for triggering increased ethylene production. Therefore, the application of benzyl adenine (BA) which is synthetic cytokinin may be suitable preservative and evidenced that the response of gerbera to spraying with BA depended on the concentration. Salicylic acid (SA) is natural phenolic secondary metabolite, in various aspects of vital processes like ethylene biosynthesis, stomatal conductance, respiration, senescence and the activation of defense systems against different pathogens is well documented (An and Mou 2011, Miura *et al.*2010). SA and sucrose treatments extended the vase life and improved flower quality with reduced respiration rate and delay senescence. Ethylene production of cut gerbera flowers increased with flower senescence and treatment with salicylic acid, an ethylene produce inhibitor, extended flower longevity.

MATERIALS AND METHODS

The experiment was conducted at Department of Horticulture, Sri Konda Laxman Telangana State Horticultural University, Hyderabad from during 2016-17. The experiment was Completely Randomized Design with three replications and during the first 10 days period, there were significant was done at least with 9 flowers for three replications. Uniform orange gerbera flowers were collected from polyhouse situated Agriculture University. These flowers were grown at uniformly maintained growing conditions. Gerbera sticks were trimmed in equal length. Slanting cut was made to provide more solution accumulated area.

The flowers were sorted out for uniform flower size so as to maintain uniformity with in the replication. The stems were subsequently cut to an even length of 45 cm, then flower stalks were placed in 600 ml bottle containing 500 ml of holding solutions of different chemical preservatives were used individually or in combinations as described separately in each experiment. In each glass bottle five flowers were placed and considered as one replication. The mouth of the bottles was closed with a plastic stopper having appropriate provision for flower scapes, which effectively averted the evaporational loss of aqueous test solutions.

The weight of each container and the test solution with and without flower scapes were recorded once in two days, while recording weights recutting of the floral stems (about 0.5 cm) was done under water. Vase life and other visual observations of the flowers were recorded daily. The aim of this experiment was to study the effect of some holding solutions, viz.

T_1 – 2% Sucrose + SA @ 100 ppm
T_2 – 2% Sucrose + SA @ 150 ppm
T_3 – 2% Sucrose + SA @ 200 ppm
T_4 – 3% Sucrose + SA @ 100 ppm
T_5 – 3% Sucrose + SA @ 150 ppm
T_6 – 3% Sucrose + SA @ 200 ppm
T_7 – 4% Sucrose + SA @ 100 ppm
T_8 – 4% Sucrose + SA @ 150 ppm
T_9 – 4% Sucrose + SA @ 200 ppm
T_{10} –2% Sucrose + BA @ 100 ppm
T_{11} – 2% Sucrose + BA @ 150 ppm
T_{12}– 2% Sucrose + BA @ 200 ppm
T_{13} – 3% Sucrose + BA @ 100 ppm
T_{14}– 3% Sucrose + BA @ 150 ppm
T_{15} – 3% Sucrose + BA @ 200 ppm
T_{16} – 4% Sucrose + BA @ 100 ppm
T_{17} – 4% Sucrose + BA @ 150 ppm
T_{18} – 4% Sucrose + BA @ 200 ppm
T_{19}– 2% Sucrose + STS @ 0.2 mM
T_{20}– 2% Sucrose + STS @ 0.4 mM
T_{21}– 2% Sucrose + STS @ 0.8 mM
T_{22}– 3% Sucrose + STS @ 0.2 mM
T_{23} – 3% Sucrose + STS @ 0.4 mM
T_{24}– 3% Sucrose + STS @ 0.8 mM
T_{25}– 4% Sucrose + STS @ 0.2 mM
T_{26}– 4% Sucrose + STS @ 0.4 mM
T_{27}– 4% Sucrose + STS @ 0.8 mM
T_{28}– Control (Distilled water)

Table 1. Effect of ethylene inhibitors on fresh weight of flower (g) of cut gerbera cv Goliath.

Treatments	Fresh weight of flower (g)			
	3rd day	6th day	9th day	Mean
T_1	104.90	88.30	66.88	86.69
T_2	103.88	79.78	61.28	81.65
T_3	102.53	70.86	57.42	76.94
T_4	105.35	91.30	68.74	88.46
T_5	104.24	82.35	62.86	83.15
T_6	103.14	74.86	58.65	78.88
T_7	104.72	94.60	70.65	89.98
T_8	104.53	85.83	64.11	84.82
T_9	103.48	76.84	59.72	80.01
T_{10}	104.12	89.40	67.32	86.95
T_{11}	103.91	81.37	61.73	82.34
T_{12}	102.68	71.53	57.76	77.32
T_{13}	105.73	92.70	69.23	89.22
T_{14}	104.34	83.57	63.42	83.78
T_{15}	103.24	75.24	59.21	79.23
T_{16}	105.62	95.30	71.14	90.69
T_{17}	104.68	86.67	64.94	85.43
T_{18}	103.40	71.64	60.00	78.35
T_{19}	105.22	90.80	67.96	87.99
T_{20}	104.13	81.56	62.20	82.63
T_{21}	102.84	72.14	58.22	77.73
T_{22}	105.52	93.10	69.92	89.51
T_{23}	104.42	84.81	63.95	84.39
T_{24}	103.35	75.49	59.55	79.46
T_{25}	105.84	96.80	71.83	91.49
T_{26}	104.77	87.45	65.41	85.88
T_{27}	103.75	78.92	60.65	81.11
T_{28}	100.47	67.42	55.85	74.58
Mean	104.10	82.88	63.59	
SEm ±	0.42	0.86	1.67	
CD@ 5%	1.26	2.58	5.00	
CD @ 1%	2.12	3.34	7.20	

T_1– 2% Sucrose + SA @ 100 ppm	T_{15} – 3% Sucrose + BA @ 200 ppm
T_2 – 2% Sucrose + SA @ 150 ppm	T_{16} – 4% Sucrose + BA @ 100 ppm
T_3 – 2% Sucrose + SA @ 200 ppm	T_{17} – 4% Sucrose + BA @ 150 ppm
T_4 – 3% Sucrose + SA @ 100 ppm	T_{18} – 4% Sucrose + BA @ 200 ppm
T_5 – 3% Sucrose + SA @ 150 ppm	T_{19}– 2% Sucrose + STS @ 0.2 mM
T_6– 3% Sucrose + SA @ 200 ppm	T_{20}– 2% Sucrose + STS @ 0.4 mM
T_7– 4% Sucrose + SA @ 100 ppm	T_{21}– 2% Sucrose + STS @ 0.8 mM
T_8– 4% Sucrose + SA @ 150 ppm	T_{22} – 3% Sucrose + STS @ 0.2 mM
T_9– 4% Sucrose + SA @ 200 ppm	T_{23} – 3% Sucrose + STS @ 0.4 mM
T_{10} – 2% Sucrose + BA @ 100 ppm	T_{24}– 3% Sucrose + STS @ 0.8 mM
T_{11} – 2% Sucrose + BA @ 150 ppm	T_{25}– 4% Sucrose + STS @ 0.2 mM
T_{12} – 2% Sucrose + BA @ 200 ppm	T_{26}– 4% Sucrose + STS @ 0.4 mM
T_{13} – 3% Sucrose + BA @ 100 ppm	T_{27}– 4% Sucrose + STS @ 0.8 mM
T_{14} – 3% Sucrose + BA @ 150 ppm	T_{28}– Control

SA= Salicylic acid; BA = Benzyl adenine; STS = Silver Thiosulfate.

RESULTS AND DISCUSSION

Fresh weight (g)

Higher fresh weight was maintained in gerbera cut flowers placed in 4% sucrose + STS 0.2 mM (105.84) on 3rd to 9th day (71.83) which was on par with 4% Sucrose + BA 100 ppm (71.14), 4% Sucrose + SA 100 ppm (70.65), 3% Sucrose + STS 0.2 mM (69.92), 3% Sucrose + BA 100 ppm (69.23) and 3% Sucrose + SA 100 ppm (68.74). Lowest values of fresh weight accompanied the control, which was recorded on 3rd day (100.47) and 9th day (55.85) of vase life shown in Table 1.

Fresh weight significantly decreased from 3rd day (104.10) to 9th day (63.59) of gerbera cut flowers. Among the ethylene inhibitors, 4% sucrose + STS @ 0.2 mM treated flowers maintained a higher relative fresh weight followed by 4% Sucrose + BA 100 ppm during entire vase life period of gerbera cv Goliath. The relative fresh weight of all non-ethylene-treated flowers declined steadily, and noticeable differences only became apparent after 6 to 7 days.

The gain in fresh weight might be due to higher solution uptake and better development of corolla. Flower freshness is lost gradually due to loss in available carbohydrates through the process of respiration. Respiration rate is increased by ethylene production in the senescing tissues. Therefore, the improvement in fresh weight observed in these studies can be attributed to the continuous supply of sucrose and thus in turn, approaching the carbohydrate starvation due to respiration.

Furthermore, STS can be act as an anti-ethylene factor resulting in reduced respiration rates and achievement of greater fresh weight. These results are in line with those obtained by Hutchinson *et al.* (2003) who mentioned that combination of sucrose and STS was the most efficient solution in obtaining largest floret spike and achieving greater fresh weight than distilled water. Amith *et al.* (2015) reported that STS also helps in inhibition of ethylene production and minimizing loss in fresh weight in cut gerbera.

Water uptake (WU g flower^{-1})

Highest water uptake was recorded in gerbera cut

Table 2. Effect of ethylene inhibitors on water uptake (g flower^{-1}) of cut gerbera cv Goliath.

Treatments	Water uptake (g. flower^{-1}) 3rd day	6th day	9th day	Mean
T_1	10.75	8.10	5.80	8.22
T_2	9.94	7.55	5.00	7.50
T_3	9.35	6.43	4.20	6.66
T_4	10.89	8.25	6.29	8.48
T_5	10.28	7.72	5.33	7.78
T_6	9.62	6.68	4.40	6.90
T_7	11.13	8.40	6.43	8.65
T_8	10.46	7.87	5.60	7.98
T_9	9.78	6.86	4.72	7.12
T_{10}	10.79	8.15	6.00	8.31
T_{11}	10.12	7.60	5.04	7.59
T_{12}	9.48	6.54	4.23	6.75
T_{13}	10.94	8.31	6.32	8.52
T_{14}	10.34	7.77	5.43	7.85
T_{15}	9.67	6.74	4.52	6.98
T_{16}	11.18	8.47	6.52	8.72
T_{17}	10.57	7.90	5.66	8.04
T_{18}	9.83	6.92	4.85	7.20
T_{19}	10.82	8.20	6.10	8.37
T_{20}	10.19	7.66	5.11	7.65
T_{21}	9.55	6.61	4.31	6.82
T_{22}	10.97	8.38	6.39	8.58
T_{23}	10.40	7.82	5.47	7.90
T_{24}	9.72	6.80	4.62	7.05
T_{25}	11.24	8.58	6.58	8.80
T_{26}	10.63	7.97	5.70	8.10
T_{27}	9.90	7.50	4.90	7.43
T_{28}	8.82	5.62	3.90	6.11
Mean	10.26	7.55	5.34	
SEm ±	0.02	0.03	0.03	
CD @ 5%	0.07	0.07	0.09	
CD @ 1%	0.17	0.32	0.67	

T_1 – 2% Sucrose + SA @ 100 ppm	T_{15} – 3% Sucrose + BA @ 200 ppm
T_2 – 2% Sucrose + SA @ 150 ppm	T_{16} – 4% Sucrose + BA @ 100 ppm
T_3 – 2% Sucrose + SA @ 200 ppm	T_{17} – 4% Sucrose + BA @ 150 ppm
T_4 – 3% Sucrose + SA @ 100 ppm	T_{18} – 4% Sucrose + BA @ 200 ppm
T_5 – 3% Sucrose + SA @ 150 ppm	T_{19} – 2% Sucrose + STS @ 0.2 mM
T_6 – 3% Sucrose + SA @ 200 ppm	T_{20} – 2% Sucrose + STS @ 0.4 mM
T_7 – 4% Sucrose + SA @ 100 ppm	T_{21} – 2% Sucrose + STS @ 0.8 mM
T_8 – 4% Sucrose + SA @ 150 ppm	T_{22} – 3% Sucrose + STS @ 0.2 mM
T_9 – 4% Sucrose + SA @ 200 ppm	T_{23} – 3% Sucrose + STS @ 0.4 mM
T_{10} – 2% Sucrose + BA @ 100 ppm	T_{24} – 3% Sucrose + STS @ 0.8 mM
T_{11} – 2% Sucrose + BA @ 150 ppm	T_{25} – 4% Sucrose + STS @ 0.2 mM
T_{12} – 2% Sucrose + BA @ 200 ppm	T_{26} – 4% Sucrose + STS @ 0.4 mM
T_{13} – 3% Sucrose + BA @ 100 ppm	T_{27} – 4% Sucrose + STS @ 0.8 mM
T_{14} – 3% Sucrose + BA @ 150 ppm	T_{28} – Control

SA= Salicylic acid, BA = Benzyl adenine STS = Silver thiosulfate.

flowers with 4% Sucrose + STS 0.2 mM (11.24 g flower^{-1}) on 3rd to 9th day (6.58 g flower^{-1}) followed by 4% Sucrose + BA 100 ppm (6.52 g. flower^{-1}) and 4% Sucrose + SA 100 ppm (6.43 g. flower^{-1}) whereas control recorded lowest water uptake on 9th day (3.90 g flower^{-1}), as seen in Table 2.

4% Sucrose + STS 0.2 mM was more effective in maintaining a greater amount of water uptake when compared to 4% sucrose + BA 100 ppm and 4% sucrose + SA 100 ppm during entire vase life period of cut gerberas and control recorded lowest water uptake on all days of vase life period. The solution uptake rates of flowers in all tested solutions were significantly greater than control and longevity reduction was also strongly associated with the capacity of water uptake by the cut flower.

STS may have a positive influence on the water uptake because of antibacterial effects of Ag^+ ions and may affect regulation of water channel activity via inhibition of sulfhydryl containing proteins and improve solution uptake reported by Niemietz and Tyerman (2002). In addition, sucrose helped in increasing water uptake and decreased the transpiration loss by decreasing stomatal opening thereby maintaining turgidity of flowers (Elhindi 2012). In addition, STS to the holding solution increased the concentrations of glucose and fructose in florets. This data suggested that STS may improve sucrose uptake and its subsequent hydrolysis (Meir *et al.* 1995).

Moreover, STS acts as an ethylene antagonist. However, silver ions from the STS complex may also be biocidal. Thus, reducing or eliminating bacterial build up in the vascular tissue of cut stems as reported for carnation. It seems that silver compounds and particles transport throughout stem vascular system and removes pathogenesis infection inside the vascular system and promote water potential of plants. Similar results were also recorded by Rezvanypour Shirin and Osfoori Mohsen (2011) in rose and Sharma and Bhardwaj (2015) in carnation.

Total loss of water (TLW g flower^{-1})

Higher TLW was recorded in gerbera cut flowers with 4% Sucrose + STS 0.2 mM from 3nd day (9.87 g flower^{-1}) to 9th day (6.87 g flower^{-1}) followed by 4% su-

Table 3. Effect of ethylene inhibitors on total loss of water (g flower^{-1}) of cut gerbera cv Goliath.

Treatments	Total loss of water (g flower^{-1}) 3rd day	6th day	9th day	Mean
T_{1}	9.56	8.52	6.41	8.16
T_{2}	9.10	8.01	5.83	7.65
T_{3}	8.68	7.20	5.36	7.08
T_{4}	9.68	8.65	6.56	8.30
T_{5}	9.28	8.15	6.14	7.86
T_{6}	8.82	7.43	5.52	7.26
T_{7}	9.80	8.77	6.72	8.43
T_{8}	9.43	8.31	6.26	8.00
T_{9}	8.95	7.72	5.67	7.45
T_{10}	9.60	8.57	6.47	8.21
T_{11}	9.16	8.05	5.87	7.69
T_{12}	8.73	7.25	5.40	7.13
T_{13}	9.71	8.69	6.60	8.33
T_{14}	9.32	8.20	6.17	7.90
T_{15}	8.86	7.53	5.57	7.32
T_{16}	9.83	8.80	6.80	8.48
T_{17}	9.47	8.37	6.30	8.05
T_{18}	9.00	7.83	5.72	7.52
T_{19}	9.64	8.61	6.51	8.25
T_{20}	9.21	8.11	5.93	7.75
T_{21}	8.77	7.32	5.46	7.18
T_{22}	9.75	8.74	6.66	8.38
T_{23}	9.37	8.25	6.20	7.94
T_{24}	8.91	7.64	5.61	7.39
T_{25}	9.87	8.86	6.87	8.53
T_{26}	9.51	8.43	6.35	8.10
T_{27}	9.05	7.95	5.77	7.59
T_{28}	8.61	5.85	5.28	6.58
Mean	9.27	8.06	6.07	
SEm ±	0.02	0.05	0.07	
CD @ 5%	0.06	0.14	0.21	
CD @ 1%	0.18	0.26	0.32	

T_{1} – 2% Sucrose + SA @ 100 ppm	T_{15} – 3% Sucrose + BA @ 200 ppm
T_{2} – 2% Sucrose + SA @ 150 ppm	T_{16} – 4% Sucrose + BA @ 100 ppm
T_{3} – 2% Sucrose + SA @ 200 ppm	T_{17} – 4% Sucrose + BA @ 150 ppm
T_{4} – 3% Sucrose + SA @ 100 ppm	T_{18} – 4% Sucrose + BA @ 200 ppm
T_{5} – 3% Sucrose + SA @ 150 ppm	T_{19} – 2% Sucrose + STS @ 0.2 mM
T_{6} – 3% Sucrose + SA @ 200 ppm	T_{20} – 2% Sucrose + STS @ 0.4 mM
T_{7} – 4% Sucrose + SA @ 100 ppm	T_{21} – 2% Sucrose + STS @ 0.8 mM
T_{8} – 4% Sucrose + SA @ 150 ppm	T_{22} – 3% Sucrose + STS @ 0.2 mM
T_{9} – 4% Sucrose + SA @ 200 ppm	T_{23} – 3% Sucrose + STS @ 0.4 mM
T_{10} –2% Sucrose + BA @ 100 ppm	T_{24} – 3% Sucrose + STS @ 0.8 mM
T_{11} – 2% Sucrose + BA @ 150 ppm	T_{25} 4% Sucrose + STS @ 0.2 mM
T_{12} – 2% Sucrose + BA @ 200 ppm	T_{26} – 4% Sucrose + STS @ 0.4 mM
T_{13} – 3% Sucrose + BA @ 100 ppm	T_{27} – 4% Sucrose + STS @ 0.8 mM
T_{14} – 3% Sucrose + BA @ 150 ppm	T_{28} – Control

SA= Salicylic acid, BA = Benzyl adenine, STS = Silver thiosulfate.

crose + BA 100 ppm (6.80 g.flower^{-1}) and 4% sucrose + SA 100 ppm (6.72 g flower^{-1}). From 9th day to last day of experimentation, TLW followed a decreasing trend with all ethylene inhibitors treatments studied. Among the ethylene inhibitor treatments, 4% Sucrose + STS 0.2 mM recorded highest TLW followed by 4% sucrose + BA 100 ppm and 4% sucrose + SA 100 ppm during entire vase life period of cut gerberas and control recorded lowest TLW on all days of vase life period presented in Table 3.

On the other hand, combination of 4% Sucrose + STS 0.2 mM recorded the highest values with regard to transpiration loss of water. Water deficit is directly related to turgor of cut flowers, which accelerates wilting and senescence. The higher water uptake might be due to higher TLW to avoid temporary water stress. Silver ions enhanced water uptake due to microbe free conducting tissues and also delaying senescence by inhibiting ethylene generation. Minimum TLW in control was due to reduced water uptake.

Water balance (WB g flower^{-1})

There were significant differences in water balance during different days of vase life period. Significantly highest water balance in cut gerbera found with 4% Sucrose + STS 0.2 mM on day 3, 6 and 9 (5.37, 3.72 and 3.71 g flower^{-1}) which was at a par with 4% Sucrose + BA 100 ppm (5.35, 3.67 and 3.72 g flower^{-1}) while the lowest WB was found with control (4.21, 3.77 and 2.62 g flower^{-1}) on day 3, 6 and 9 respectively were shown Table 4.

The differences between water up take and water loss (water balance) determines the quality and longevity of cut flowers. The reduction in water uptake coupled with continuous transportation leads to water deficit and reduced turgidity in the cut flowers (Emangor 2004). The sugars improve the water balance and osmotic potential of cut flowers and therefore, delay flowers senescence (Halevy and Mayak 1981). As a result of the decrease in water potential, water enters more rapidly, causing cell expansion and diluting the sugars in the tissues.

Sucrose is useful as respiratory substrate and as an osmilite that helps in the maintenance of a favor-

Table 4. Effect of ethylene inhibitors on water balance (g flower^{-1}) of cut gerbera cv Goliath.

Treatments	Water balance (g flower^{-1}) 3rd day	6th day	9th day	Mean
T_1	5.19	3.58	3.39	4.05
T_2	4.84	3.54	3.17	3.85
T_3	4.67	3.23	2.84	3.58
T_4	5.21	3.60	3.73	4.18
T_5	5.00	3.57	3.19	3.92
T_6	4.80	3.25	2.88	3.64
T_7	5.33	3.63	3.71	4.22
T_8	5.03	3.56	3.34	3.98
T_9	4.83	3.14	3.05	3.67
T_{10}	5.19	3.58	3.53	4.10
T_{11}	4.96	3.55	3.17	3.87
T_{12}	4.75	3.29	2.83	3.62
T_{13}	5.23	3.62	3.72	4.19
T_{14}	5.02	3.57	3.26	3.95
T_{15}	4.81	3.21	2.95	3.66
T_{16}	5.35	3.67	3.72	4.25
T_{17}	5.10	3.53	3.36	4.00
T_{18}	4.83	3.09	3.13	3.68
T_{19}	5.18	3.59	3.59	4.12
T_{20}	4.98	3.55	3.18	3.90
T_{21}	4.78	3.29	2.85	3.64
T_{22}	5.22	3.64	3.73	4.20
T_{23}	5.03	3.57	3.27	3.96
T_{24}	4.81	3.16	3.01	3.66
T_{25}	5.37	3.72	3.71	4.27
T_{26}	5.12	3.54	3.35	4.00
T_{27}	4.85	3.55	3.13	3.84
T_{28}	4.21	3.77	2.62	3.53
Mean	4.99	3.49	3.26	
SEm ±	0.13	0.16	0.25	
CD @ 5%	0.39	0.48	0.75	
CD @ 1%	0.47	0.69	0.92	

T_1 – 2% Sucrose + SA @ 100 ppm	T_{15} – 3% Sucrose + BA @ 200 ppm
T_2 – 2% Sucrose + SA @ 150 ppm	T_{16} – 4% Sucrose + BA @ 100 ppm
T_3 – 2% Sucrose + SA @ 200 ppm	T_{17} – 4% Sucrose + BA @ 150 ppm
T_4 – 3% Sucrose + SA @ 100 ppm	T_{18} – 4% Sucrose + BA @ 200 ppm
T_5 – 3% Sucrose + SA @ 150 ppm	T_{19} – 2% Sucrose + STS @ 0.2 mM
T_6 – 3% Sucrose + SA @ 200 ppm	T_{20} – 2% Sucrose + STS @ 0.4 mM
T_7 – 4% Sucrose + SA @ 100 ppm	T_{21} – 2% Sucrose + STS @ 0.8 mM
T_8 – 4% Sucrose + SA @ 150 ppm	T_{22} – 3% Sucrose + STS @ 0.2 mM
T_9 – 4% Sucrose + SA @ 200 ppm	T_{23} – 3% Sucrose + STS @ 0.4 mM
T_{10} –2% Sucrose + BA @ 100 ppm	T_{24} – 3% Sucrose + STS @ 0.8 mM
T_{11} – 2% Sucrose + BA @ 150 ppm	T_{25} – 4% Sucrose + STS @ 0.2 mM
T_{12} – 2% Sucrose + BA @ 200 ppm	T_{26} – 4% Sucrose + STS @ 0.4 mM
T_{13} – 3% Sucrose + BA @ 100 ppm	T_{27} – 4% Sucrose + STS @ 0.8 mM
T_{14} – 3% Sucrose + BA @ 150 ppm	T_{28} – Control

SA= Salicylic acid, BA = Benzyl adenine, STS = Silver thiosulfate.

able water balance. Sucrose in the holding solution reduced stomatal aperture in rose cut flower, thus reducing water loss and improving water retention and solution uptake capacity. Presence of silver in the holding solution maintained the osmotic pressure potential of the petal cells thus improving their water balance and promote longevity. The present results of increased WB were in accordance with the findings of Sharma (2013) in carnation.

Flower stalk bending (Degrees)

The flower stalk bending differed significantly due to different combinations of sucrose and ethylene inhibitor treatments of cut gerberas. Flower stalk bending was lowest in 4% Sucrose + STS 0.2 mM (5.39) which was significantly superior over all other treatments followed by 4% sucrose + BA 100 ppm (6.16 degrees) and 4% sucrose + SA 100 ppm (6.69 degrees). The highest flower stalk bending was noticed in control (33.41 degrees) and intermediate results registered in rest of the treatments were seen in Table 5.

Significantly lowest flower stalk bending was recorded with 4% Sucrose + STS @ 0.2 mM on day 3, 6 and 9 (0.75, 2.85 and 12.57 degrees) followed by 4% sucrose + BA 100 ppm (0.82, 3.54 and 14.13 degrees) and 4% sucrose + SA 100 ppm (1.13, 4.12 and 14.82 degrees). From 9th day to last day of experimentation, flower stalk bending followed an increasing trend with all ethylene inhibitors treatments studied. The flower stalk bending significantly increased at each successive interval of observation from day 1 (0.00 degrees) to day 9 (32.12 degrees). The lowest scape bending with Sucrose 4%+ STS @ 0.2 mM could be attributed to the development of secondary thickening and lignifications of vascular elements.

The vase life of gerbera is substantially dependent on the how upright the stem is, or in scientific terms, depends on bent neck. The slowest scape bending was found in the gerbera kept in the treatment of sugar and STS solution. Sugar acts as the carbohydrate source and also makes the cells of the gerbera stem concentrated with sugars that are carried up by the phloem. The hypertonic solutions inside the cells allow water to enter the cells by osmosis and therefore make them turgid. This turgidity gives

Table 5. Effect of ethylene inhibitors on flower stalk bending (Degrees) of cut gerbera cv Goliath.

Treatments	Flower stalk bending (Degrees) 3rd day	6th day	9th day	Mean
T_1	1.78	7.83	22.84	10.82
T_2	2.68	16.52	36.45	18.55
T_3	3.64	25.94	51.64	27.07
T_4	1.42	5.97	17.85	8.41
T_5	2.38	13.85	33.27	16.50
T_6	3.24	22.75	44.74	23.58
T_7	1.13	4.12	14.82	6.69
T_8	2.00	10.37	28.52	13.63
T_9	2.94	19.54	41.36	21.28
T_{10}	1.61	7.35	21.15	10.04
T_{11}	2.52	15.66	35.43	17.87
T_{12}	3.42	24.48	49.12	25.67
T_{13}	1.36	5.42	17.27	8.02
T_{14}	2.27	12.24	31.58	15.36
T_{15}	3.16	21.85	43.25	22.75
T_{16}	0.82	3.54	14.13	6.16
T_{17}	1.47	9.42	26.74	12.54
T_{18}	2.86	18.63	40.14	20.54
T_{19}	1.54	6.48	18.72	8.91
T_{20}	2.47	14.17	34.91	17.18
T_{21}	3.38	23.55	47.85	24.93
T_{22}	1.27	4.85	15.44	7.19
T_{23}	2.14	11.64	30.63	14.80
T_{24}	3.08	21.63	42.56	22.42
T_{25}	0.75	2.85	12.57	5.39
T_{26}	1.82	8.57	25.61	12.00
T_{27}	2.75	17.41	38.23	19.46
T_{28}	5.53	32.27	62.43	33.41
Mean	2.37	13.89	32.12	
SEm ±	0.12	0.37	0.76	
CD @ 5%	0.36	1.11	2.28	
CD @ 1%	0.42	1.83	3.24	

T_1 – 2% Sucrose + SA @ 100 ppm
T_2 – 2% Sucrose + SA @ 150 ppm
T_3 – 2% Sucrose + SA @ 200 ppm
T_4 – 3% Sucrose + SA @ 100 ppm
T_5 – 3% Sucrose + SA @ 150 ppm
T_6 – 3% Sucrose + SA @ 200 ppm
T_7 – 4% Sucrose + SA @ 100 ppm
T_8 – 4% Sucrose + SA @ 150 ppm
T_9 – 4% Sucrose + SA @ 200 ppm
T_{10} – 2% Sucrose + BA @ 100 ppm
T_{11} – 2% Sucrose + BA @ 150 ppm
T_{12} – 2% Sucrose + BA @ 200 ppm
T_{13} – 3% Sucrose + BA @ 100 ppm
T_{14} – 3% Sucrose + BA @ 150 ppm
T_{15} – 3% Sucrose + BA @ 200 ppm
T_{16} – 4% Sucrose + BA @ 100 ppm
T_{17} – 4% Sucrose + BA @ 150 ppm
T_{18} – 4% Sucrose + BA @ 200 ppm
T_{19} – 2% Sucrose + STS @ 0.2 mM
T_{20} – 2% Sucrose + STS @ 0.4 mM
T_{21} – 2% Sucrose + STS @ 0.8 mM
T_{22} – 3% Sucrose + STS @ 0.2 mM
T_{23} – 3% Sucrose + STS @ 0.4 mM
T_{24} – 3% Sucrose + STS @ 0.8 mM
T_{25} – 4% Sucrose + STS @ 0.2 mM
T_{26} – 4% Sucrose + STS @ 0.4 mM
T_{27} – 4% Sucrose + STS @ 0.8 mM
T_{28} – Control

SA= Salicylic acid, BA = Benzyl adenine, STS = Silver thiosulfate.

the stem a rigid, upright structure. STS has certain antimicrobial properties, which reduce the degree of vascular blockage, thus allowing for optimum solution uptake and reducing stem bending (Khan *et al.* 2015). Additionally, STS is markedly effective in extending the vase life of cut gerbera which controls higher antibacterial properties and suppress stem bending more effectively (Siresha and Reddy 2016).

Flower diameter (cm)

Flower diameter significantly decreased from 3rd (11.34 cm) day to 9th day (7.65 cm) followed by 4% Sucrose + BA 100 ppm (7.53cm) and 4% sucrose + SA 100 ppm (7.38 cm) and minimum flower diameter was recorded in control (4.38 cm). The remaining all other treatments have recorded intermediate values were depicted in Table 6.

Sucrose is a soluble carbohydrate and can act as a substrate for respiration. STS is a good option to be used as a biocide and can provide a good acidic medium. Thus the combination of these chemicals improved the flower size of cut roses as a result of better intake of nutrients and post harvest developmental stages such as respiration. (Sikandar Hayat *et al.* 2012). Similar findings reported by Rezvanypour Shirin and Osfoori Mohsen (2011) in rose and Sharma and Bhardwaj (2015) also confirmed with similar observations in carnation.

Vase life (Days)

There was a significant difference in vase life as influenced by ethylene inhibitors in cut gerbera cv Goliath. Significantly higher percent increase in vase life was recorded with 4% Sucrose + STS 0.2 mM (124.16 %) followed by 4% Sucrose + BA 100 ppm (118.70 %) and 4% Sucrose + SA 100 ppm (114.91%) (Table 7).

Antimicrobial and ethylene inhibiting effects of STS might have contributed to longer shelf life by increasing water uptake thereby improving water relations and inhibiting ethylene production. STS by totally inhibiting ACC (Amino cyclopropane-1-carboxylic acid) accumulation might have stopped the activity of ACC synthase and ethylene forming

Table 6. Effect of ethylene inhibitors on flower diameter (cm) of cut gerbera cv Goliath.

Treatments	Flower diameter (cm) 3rd day	6th day	9th day	Mean
T_1	10.93	9.00	7.00	8.98
T_2	10.53	7.76	6.58	8.29
T_3	9.38	6.88	5.54	7.27
T_4	11.00	9.37	7.22	9.20
T_5	10.68	8.00	6.67	8.45
T_6	9.78	7.25	5.77	7.60
T_7	11.34	9.64	7.38	9.45
T_8	10.77	8.33	6.83	8.64
T_9	9.94	7.54	5.91	7.80
T_{10}	10.93	9.15	7.12	9.07
T_{11}	10.58	7.84	6.60	8.34
T_{12}	9.52	7.00	5.66	7.39
T_{13}	11.14	9.43	7.27	9.28
T_{14}	10.73	8.12	6.72	8.52
T_{15}	9.83	7.37	5.83	7.68
T_{16}	11.23	9.72	7.53	9.49
T_{17}	10.82	8.81	6.87	8.83
T_{18}	10.00	7.54	5.97	7.84
T_{19}	10.92	9.24	7.25	9.14
T_{20}	10.62	7.93	6.60	8.38
T_{21}	9.73	7.13	5.72	7.53
T_{22}	11.21	9.55	7.32	9.36
T_{23}	10.73	8.33	6.78	8.61
T_{24}	9.88	7.43	5.87	7.73
T_{25}	11.34	9.87	7.65	9.62
T_{26}	10.87	8.87	6.93	8.89
T_{27}	10.11	7.68	6.52	8.10
T_{28}	8.87	6.57	4.38	6.61
Mean	10.48	8.26	6.55	
SEm ±	0.02	0.02	0.02	
CD @ 5%	0.07	0.06	0.06	
CD @ 1%	0.29	0.11	0.21	

T_1 – 2% Sucrose + SA @ 100 ppm; T_2 – 2% Sucrose + SA @ 150 ppm; T_3 – 2% Sucrose + SA @ 200 ppm; T_4 – 3% Sucrose + SA @ 100 ppm; T_5 – 3% Sucrose + SA @ 150 ppm; T_6 – 3% Sucrose + SA @ 200 ppm; T_7 – 4% Sucrose + SA @ 100 ppm; T_8 – 4% Sucrose + SA @ 150 ppm; T_9 – 4% Sucrose + SA @ 200 ppm; T_{10} – 2% Sucrose + BA @ 100 ppm; T_{11} – 2% Sucrose + BA @ 150 ppm; T_{12} – 2% Sucrose + BA @ 200 ppm; T_{13} – 3% Sucrose + BA @ 100 ppm; T_{14} – 3% Sucrose + BA @ 150 ppm; T_{15} – 3% Sucrose + BA @ 200 ppm; T_{16} – 4% Sucrose + BA @ 100 ppm; T_{17} – 4% Sucrose + BA @ 150 ppm; T_{18} – 4% Sucrose + BA @ 200 ppm; T_{19} – 2% Sucrose + STS @ 0.2 mM; T_{20} – 2% Sucrose + STS @ 0.4 mM; T_{21} – 2% Sucrose + STS @ 0.8 mM; T_{22} – 3% Sucrose + STS @ 0.2 mM; T_{23} – 3% Sucrose + STS @ 0.4 mM; T_{24} – 3% Sucrose + STS @ 0.8 mM; T_{25} – 4% Sucrose + STS @ 0.2 mM; T_{26} – 4% Sucrose + STS @ 0.4 mM; T_{27} – 4% Sucrose + STS @ 0.8 mM; T_{28} – Control

SA= Salicylic acid, BA = Benzyl adenine, STS = Silver Thiosulfate.

Table 7. Effect of ethylene inhibitors on vase life of cut gerbera cv Goliath.

Treatments	Vase life (Days)	Per cent increase in vase life over control
T_1	8.91	87.18
T_2	7.27	52.73
T_3	5.61	17.86
T_4	9.58	101.26
T_5	7.87	65.34
T_6	6.24	31.09
T_7	10.23	114.91
T_8	8.39	76.26
T_9	6.72	41.18
T_{10}	9.11	91.39
T_{11}	7.49	57.35
T_{12}	5.86	23.10
T_{13}	9.78	105.46
T_{14}	8.00	68.06
T_{15}	6.42	34.87
T_{16}	10.41	118.70
T_{17}	8.58	80.25
T_{18}	6.89	44.75
T_{19}	9.36	96.64
T_{20}	7.65	60.71
T_{21}	6.00	26.05
T_{22}	10.00	110.08
T_{23}	8.20	72.27
T_{24}	6.60	38.66
T_{25}	10.67	124.16
T_{26}	8.73	83.40
T_{27}	7.14	50.00
T_{28}	4.76	0.00
Mean	7.95	
SEm ±	0.22	
CD @ 5%	0.66	
CD @ 1%	0.92	

T_1 – 2% Sucrose + SA @ 100 ppm; T_2 – 2% Sucrose + SA @ 150 ppm; T_3 – 2% Sucrose + SA @ 200 ppm; T_4 – 3% Sucrose + SA @ 100 ppm; T_5 – 3% Sucrose + SA @ 150 ppm; T_6 – 3% Sucrose + SA @ 200 ppm; T_7 – 4% Sucrose + SA @ 100 ppm; T_8 – 4% Sucrose + SA @ 150 ppm; T_9 – 4% Sucrose + SA @ 200 ppm; T_{10} – 2% Sucrose + BA @ 100 ppm; T_{11} – 2% Sucrose + BA @ 150 ppm; T_{12} – 2% Sucrose + BA @ 200 ppm; T_{13} – 3% Sucrose + BA @ 100 ppm; T_{14} – 3% Sucrose + BA @ 150 ppm; T_{15} – 3% Sucrose + BA @ 200 ppm; T_{16} – 4% Sucrose + BA @ 100 ppm; T_{17} – 4% Sucrose + BA @ 150 ppm; T_{18} – 4% Sucrose + BA @ 200 ppm; T_{19} – 2% Sucrose + STS @ 0.2 mM; T_{20} – 2% Sucrose + STS @ 0.4 mM; T_{21} – 2% Sucrose + STS @ 0.8 mM; T_{22} – 3% Sucrose + STS @ 0.2 mM; T_{23} – 3% Sucrose + STS @ 0.4 mM; T_{24} – 3% Sucrose + STS @ 0.8 mM; T_{25} – 4% Sucrose + STS @ 0.2 mM; T_{26} – 4% Sucrose + STS @ 0.4 mM; T_{27} – 4% Sucrose + STS @ 0.8 mM; T_{28} – Control

A= Salicylic acid, BA = Benzyl adenine, STS = Silver Thiosulfate.

enzyme in the petals resulting in reduced ethylene production and extended vase life. However, combined treatment with STS and sucrose may be preferable for improving the vase-life of cut gerbera (Table 7). Moreover, longest vase life of cut gerbera with optimal concentration of sucrose was due to better water relations in floral tissue and also probably due to use of sucrose in the vase solution.

CONCLUSION

The present study has shown that the vase life and stem bending in gerbera cut flower vary with the concentration of various chemicals. Ethylene inhibitors treated flowers ability in high water uptake and fresh weight of flower are the main factors that lead for stem strength and straightness and for the long vase life which indicates the postharvest longevity. Effects of vase solutions with silver thiosulfate (STS 0.2 mM) in combination with sucrose (4%) manifested better results compared to other treatments in terms of Fresh weight of flower, Water Uptake, Total loss of water, Water balance, Flower stalk bending, Flower diameter and Vase life of cut gerbera.

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REFERENCES

Amith R, Patil RM, Paramagoudar P, Chikkasubbanna V (2015) Effect of chemical floral preservatives on vase life of cut flowers of Gerbera cv Winter Queen. *Environ Ecol* 33(1): 148-151.

An FC, Mou Z (2011) Salicylic acid and its function in plant immunity. J Integrative Pl Biol. 53(6): 412-428.

Elhindi KM (2012) Evaluation of several holding solutions for prolonging vase life and keeping quality of cut sweet pea flowers (*Lathyrus odoratus* L.). *Saudi J Biol Sci* 90: 195-202.

Emongor VE (2004) Effects of gibberellic acid on post harvest quality and vase life of Gerbera cut flowers (*Gerbera jamesonii*). *J Agron* 3: 191-195.

Halevy AH, Mayak S (1981) Senescence and postharvest physiology of cut flower. Part 2. *Horticult Rev* 3: 59-146.

Hutchinson MJ, Chebet DK, Emongor VE (2003) Effect of accel, sucrose, and silver thiosulfate on the water relations and post harvest physiology of cut tuberose flowers. Journal of African Crop Science. 11(4): 279-287.

Khan P, Shahrin S, Taufique T, Mehraj H, Jamal Uddin AFM (2015) Chemical preservatives for increasing shelf life of Gerbera. *J Biosci Agric Res* 5(1): 30-36.

Mehraj H, Ona AF, Taufique T, Mutahera S, Jamal Uddin AFM (2013a) Vase life quality improvement of white snowball using vase life extending solutions. *Bangladesh Res Publ J* 8 (3): 191-194.

Meir S, Philosoph SH, Michaeli R, Davidson H, Fogelman M, Shaffer A, Fjeld T, Stromme E (1995) Improvement of the keeping quality of mini-gladiolus spikes during prolonged storage by sucrose pulsing and modified atmosphere packaging. *Acta Hortic* 405: 335-342.

Miura K, Lee J, Miura T, Hasegawa PM (2010) Siz1 controls cell growth and plant development in Arabidopsis through sali cylic acid. *Pl Cell Physiol*. 51(1): 103-113.

Niemietz CM, Tyerman SD (2002) New potent inhibitors of aquaporins: Slver and gold compounds inhibit aquaporins of plant and human origin. *FEBS Lett* 531(3): 443-447.

Sharma S (2013) Effect of polyamines, biocides and ethylene inhibitors on extension of vase life of carnation (*Dianthus caryophyllus* L.) cut flower. MSc thesis. Submitted to DrY.S.R. Horticultural University. Venkataramannagudem.

Sharma R, Bhardwaj S (2015) Effect of silver thiosulFate, silver nitrate and distilled water on flower quality and vase life of cut carnation flowers. The Bioscan 10(4): 1483-1487.

Sikandar Hayat, Noor Ul Amin, Muhammad Ali khan, Tarek MA Soliman, Ma Nan, Kashif Hayat, Imran Ahmad, Muhammad Rezaul Kabir, Liang Jun Zhao (2012) Impact of silver thiosulfate and sucrose solution on the vase life of rose cut flower cv Cardinal. *Adv Environm Biol* 6 (5): 1643-1649.

Siresha M, Reddy MV (2016) Effect of hydration treatments on keeping quality of gerbera flower. *Int J Adv Res* 4(9): 1866-1871.