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Effect of Humic Acid on Vase Life of Gerbera Flowers After Cutting

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Abstract: Gerbera or Transvaal daisy (*Gerbera jamesonii* Hook) is one of 10 most important cut flowers in the world. One of the most problems faced the flowers is the short-life after harvest and neck bending. Producers want to increase longevity of these flowers with using chemical solutions. The aim of this experiment was to study the effect of some holding solutions, viz. distilled water (control), humic acid at 25 and 50 ml/l and solution (A) [Silver nitrate (150 mg/l) + Salicylic acid (150 mg/l) + sucrose (2%) + 8-Hydroxyquinoline citrate (8-HQC 200 mg/l)] and different storage periods and their interaction to identify the best treatments to increase flower vase life and other related characters of cut gerbera. The obtained data exhibited that all preservatives solutions caused a marked increment in the studied characters compared to that registered from distilled water (control). In this respect, the individual treatments with either solution (A) or humic acid at 25 and 50 ml/l significantly prolonged vase life, increased the number of open disk florets and water uptake of cut flowers. Moreover, the combined treatments of solution (A) plus humic acid at 25 or 50 ml/l had a superior effect on extending life of flowers, increasing flower diameter (cm) and flowers fresh weight percentage. Control treatment (distilled water) gave the highest percentage of stem curvature after 8 days with recording values higher than 88%, whereas the combination between solution (A) and humic acid either at 25 or 50 ml/l recorded the highest delay for bending neck symptoms. Concerning the effect of storage period, the export conditioning (dry cool storage for 10 days) has shown favourable results on vase life and the other studied characters but 0 days (unstored flowers) surpassed significantly the storage for 10 days. The results of interaction showed that all holding solutions with storage for 0 days (unstored flowers) had the highest effect on reducing the depletion of sugars content, increasing anthocyanin content in flowers and in turn extending vase life. In this respect, the utmost high values of this character was the treatment of holding flowers in solution (A) plus 25 ml/l humic acid x storage at 0 days (unstored flowers). Treatment of the combination of solution (A) plus humic acid at 50 ml/l x storage at 0 days was occupied the second rank in improving studied characters.

Key words: Gerbera cut flowers · Humic acid · Silver nitrate · Salicylic acid · Vase life · Stem curvature

INTRODUCTION

Gerbera (*Gerbera jamesonii* Hook) popularly known as Transvaal daisy, belongs to the Asteraceae family, which is a perennial Mediterranean plant. Gerbera is considered to be the native of South African and Asiatic regions. It is mostly found inhabit temperate and mountainous regions. Gerberas are grown for garden decoration also as cut flowers for interior decoration and for making bouquets and in dry flower crafts. They are easy to grow, light weight flowers with long (50-70cm) and slender flower stalk, exquisite petal arrangements with different shades of attractive colours and moderate vase life, all in a combined way renders gerbera flowers to a prominent position amongst the elite group of top ten cut flowers (the fourth place) of the international flower markets [1]. It is in considerable demand in both domestic and export markets. Keeping quality is an important parameter for evaluation of cut flower quality, for both domestic and export markets. One of the most important problems of postharvest of Gerbera is bent neck and less vase life. Addition of chemical preservatives to the holding solution is recommended to prolong the vase-life of cut flowers. All holding solutions must essentially contain two components viz., sugar and germicides. Sucrose is

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widely used in floral preservatives, which acts as a food source or respiratory substrate and delays the degradation of proteins and improves the water balance of cut flowers, while the germicides control harmful bacteria and prevent plugging of the conducting tissues. Therefore, the techniques of prolonging the vase-life of flowers will be a great asset to the growers and users [2]. In this regard, Meman and Dabhi [3] mentioned that the vase solution of sucrose at 4% +8–HQC at 250 ppm + citric acid at 250 ppm increased fresh weight of *Gerbera jamesonii* cv. Savana Red flowers by promoting solution uptake, improving the vase life and useful life of flowers, opening of disc florets, with bright, shining red colour and freshness for a longer duration. Likewise, Amiri *et al.* [4] reported that using a combination of 30 ppm sucrose + 250 ppm $AgNO_3$ + 250 ppm citric acid improved water uptake and consequently extended vase life, delayed scape bending, wilting and the curvature of the stem in the end of vase life of *Gerbera jamesonii* cv. Pags flowers. The cut gerbera flowers often bend and break when they are placed in water, but including antibacterial compounds such as silver nitrate in the vase water decreased the number of bent scapes [5].

Salicylic acid is a natural phenolic compound and as such is an internal regulator of growth in most plants. In recent years, a large body of evidence has demonstrated that salicylic acid plays an important regulatory role in multiple physiological processes in plants. Salicylic acid, as a key molecule has an important role in plant responses to various environmental stresses such as that from oxidative and pollution stress to pathological factors. Salicylic acid, by activating antioxidant enzymes delays the process of senescence in flowers. Salicylic acid applied as a preservative solution decreases lipid production per oxidation and in this way delays senescence. The permeability and peroxidation reduction of membrane lipids is as the result of the antioxidant enzyme activity of this compound that neutralizes free radicals from oxygen that increase during senescence. It is also possible that salicylic acid inhibition is related to inhibition of ethylene synthesis and ethylene itself in cut carnation flowers [6]. Humic acid (HA) might benefit plant growth by improving nutrient uptake and hormonal effects. Higher HA levels extended the vase life of harvested Gerbera flowers by 2-3.66 days and could prevent and delay bent neck incidence. These postharvest responses were most probably due to Ca accumulation in scapes and hormone-like activity of HA [7].

Cold storage facilitates the preservation of commodities and aims at maintenance of the harvested cut flowers in ‘fresh’ condition, markedly affecting the consumer acceptability thus, rendering storage as an important procedure in supply and demand regulation. Singh *et al*. [8] reported that to regulate the supply of flowers in the market, their refrigerated storage holds considerable promise. Flowers are stored in partially permeable plastic bags to prevent the loss of moisture and to allow limited gaseous exchange during dry storage. The rate of ethylene production and ethylene induced disorders are greatly reduced at lower storage temperatures which in turn increases the post harvest lasting quality of cut carnation flowers [9]. At low temperature the metabolic and physical activities of the pests and diseases are arrested resulting in improvement in quality and reduction in post harvest losses of Lilium inflorescences [10]. The curvature of the stem before and after storage and after turgor was regained when the flowers were placed in water.

Therefore, the work embodied in this paper aimed to increase flower vase life and other related characters of cut gerbera flowers.

MATERIALS AND METHODS

This study was carried out at Post-Harvest Lab. of Floriculture Department, Horticulture Research Institute, Giza, Egypt, during two successive seasons (2012 and 2013). *Gerbera jamesonii* Hook flowers cv. ‘Dalma’ is a creamish white coloured flower. The desired flowers were freshly obtained on January, 1st for both seasons in the morning from a commercial farm and then immediately taken to the laboratory. Flowers were harvested at their commercial stage which had two rows of outer florets open on the central disk [11]. Flowers were precooled by placing in ice cold water for 2 hours to remove the effect of high field heat. Stem bases were recut in air before treatments and stems were adjusted to 60 cm long. The flowers were divided into two groups: flowers were placed in a vase (500 ml) containing 300 ml holding solution with:

- Control, distilled water (D.W).
- Humic acid (50 ml/l).
- Humic acid (25 ml/l).
- Solution (A) = silver nitrate (150 mg/l) + salicylic acid (150 mg/l) + sucrose (2%) + 8- Hydroxyquinoline citrate (8- HQC 200 mg/l).
- Humic acid (50 ml/l) + solution (A)
- Humic acid (25 ml/l) + solution (A)

These treatments were carried out under lab conditions (0 days) of 22±2°C, 50-60% RH and 24 hrs light with fluorescent lamps to complete vase life. The other group was wrapped in tightly sealed polyethylene film (30 micron thickness) then packed in carton boxes (102 x 50 x 30 cm) to be stored at 5°C for 10 days. At the end of the storage period, packaging of flowers was removed and the stem end was recut. Flowers were placed in a vase (500 ml) containing 300 ml holding solution as mentioned above under lab conditions to complete vase life.

Measurements:

- The end of vase life (days) was determined with visible wilting of petals and their rolling to the outer part [11].
- Flower diameter (cm).
- The percentage of increase in fresh weight during vase life.
- Water uptake (cm^3).
- Number of open rows of disk florets after 14 days.
- Stem curvature (%).
- Total sugars (%) in flowers were determined calorimetrically according to the method described by Dubois *et al.* [12].
- Anthocyanin content in fresh petal samples was determined calorimetrically according to Husia *et al.* [13].

Layout of the experiment was completely randomized design in a 6 x 2 factorial arrangement with three replicates, each replicate contained 3 flowers.

Statistical Analysis: The obtained data were statistically analyzed according to Snedecor and Cochran [14] and means were compared by Least Significant Difference (L.S.D) test at the 5% level of probability in the two seasons.

RESULTS AND DISCUSSION

Effect of Holding Solutions, Storage Periods and their Interactions on Flower Traits of Cut *Gerbera jamesonii* Hook cv. 'Dalma':

Flower Vase Life: Data presented in Table 1 exhibit that vase life was significantly increased in the two seasons by holding the flowers in all preservative solutions compared with that gained from holding in distilled water.

Table 1: Effect of holding solutions, storage periods and their interactions on flower traits of cut *Gerbera jamesonii* Hook. cv. 'Dalma' during 2012 and 2013 seasons

Treatment	Vase life (day)			Stem curvature (%)		
	Storage periods (B)					
Holding solutions (A)	0 days	10 days	Mean (A)	0 days	10 days	Mean (A)
1st season						
Control (D. W)	10.67	7.00	8.85	86.00	90.00	88.00
Humic acid (50 ml/l)	17.00	12.60	14.63	45.52	49.00	47.26
Humic acid (25 ml/l)	18.12	13.53	15.82	42.50	47.00	44.75
Solution(A)*	19.83	16.00	17.92	33.00	39.75	36.38
Humic acid (50 ml/l) +A	22.0	18.00	20.00	16.00	23.00	19.50
Humic acid (25 ml/l) +A	23.55	18.67	21.11	11.12	20.10	15.61
Mean (B)	18.48	14.30	--	39.02	44.81	--
2nd season						
Control (D. W)	9.11	6.33	7.72	88.54	90.63	89.58
Humic acid (50 ml/l)	16. 42	12.00	14.21	46.32	48.80	47.56
Humic acid (25 ml/l)	17.65	12.76	15.20	44.22	47.35	45.78
Solution(A)*	19.30	15.77	17.53	36.18	41.43	38.81
Humic acid (50 ml/l)+A	21.45	17.73	19.59	16.52	24.13	20.33
Humic acid (25 ml/l) +A	23..35	18.42	20.83	12.39	20.80	16.59
Mean (B)	17.86	13.84	--	40.69	45.52	--

LSD 0.05	Vase life (day)			Stem curvature (%)		
	Holding solutions (A)	Storage periods (B)	AXB	Holding solutions (A)	Storage periods (B)	A x B
1st season	2.50	1.44	3.54	2.56	1.47	3.62
2nd season	2.55	1.47	3.60	2.62	1.51	3.71

Solution (A)* = silver nitrate (150 mg/l)+salicylic acid (150mg/l)+2% sucrose + 8- Hydroxyquinoline citrate (8- HQC 200 mg/l)

Moreover, the significantly highest values of flower vase life were recorded for the flowers held in solution (A) plus humic acid either at 25 or 50 ml/l solution. However, the prevalence was for 25 ml/l humic acid + solution A which gave the longest vase life in both seasons. This may indicate the role of humic acid (HA) in extending the vase life of harvested Gerbera flowers by 2-3.66 days due to Ca accumulation in scapes and hormone-like activity of HA[7]. Other observations were also noticed by Chamani *et al.* [15] on cut Alstroemeria which clear that lower concentrations of humic acid (100 ppm) had positive effects on flower vase life. Regarding the effect of storage periods, it was noticed that storage for 0 day had the longest vase life (18.48 days in 1st season and 17.86 days in 2nd one, compared to 10 days cold storage (14.30 days in the 1st season and 13.84 days in the 2nd one). However, export conditioning (dry cool storage) has shown favourable results on vase life of the cut Gerbera flowers which ranged between 7.00 to 18.67 days in the 1st season and 6.33 to 18.42 days in the 2nd one (Table 1). Dry cool storage can be helpful to hold Lilium inflorescences for a longer duration. At low temperature the metabolic and physical activities of the pests and diseases are arrested resulting in improvement in quality and reduction in post harvest losses of Lilium inflorescences [10].

Concerning the effect of interaction (holding solutions x storage periods) the results cleared that all holding solutions with storage for 0 day surpassed significantly the cold storage for 10 days. However, the most effective treatment in this regard was the treatment of holding in solution (A) plus humic acid at 25 ml/l x 0 day storage followed by x 10 days cold storage during the two seasons. These results are in harmony with those of Safa *et al.* [11] on *Gerbera jamesonii* L. cv. 'Balance' who indicated that the maximum vase life was obtained in 10 mg l^{-1} silver nanoparticles. Nair *et al.* [2] on *Gerbera jamesonii* reported that the maximum number of days was recorded in 20 ppm $AgNO_3$+6% sucrose treatment. He added that the improvement in vase-life of cut flowers in 20 ppm silver nitrate ($AgNO_3$) solution might be due to the fact that it is a very effective biocide, which completely inhibits the microbial growth. Also, Awad *et al.* [16] attributed the beneficial effect of $AgNO_3$ on the vase-water to the production of Ag^+ ions, which might inhibit the rise of ethylene precursor, thereby enhancing the longevity of cut flowers. Zamani *et al*. [17] on cut rose flowers reported that salicylic acid is an ethylene biosynthesis inhibitor that blocks the induction effect of ethylene on ACC oxidase activity thus reduced the senescence of the flowers and consequently increase vase life. Dhekney *et al*. [18] on cut rose Cv. 'First Red' recorded maximum vase life (7 days) with salicylic acid at 50 ppm as compared to control (5.33 days) and also with $AgNO_3$ at 200ppm + sucrose + citric acid (10.33 days). Singh and Arora [19] reported that cut stems of chrysanthemums maintained very high water potential of flowers and leaves when held in solutions of 8-HQC, $AgNO_3$ and chrysal which improved the vase life of flowers.

Stem Curvature (%): The stem curvature (%) phenomenon in gerbera flowers occurred in the present study after 8 days in the flowers held in distilled water with values higher than 88% as shown in Table 1, except for flowers held in humic acid treatments and solution (A), as such phenomenon appeared in these two solutions after 15 days while in the holding solution of humic acid at 25 ml/l plus solution (A), this phenomenon was delayed up to 21 in both seasons. Generally all preservative solutions significantly lowered stem curvature (%) of gerbera cut flowers (which ranged from 47.26 to 15.61% in the 1st season and from 47.56 to 16.59 % in the 2nd one) compared to flowers held in distilled water (88.00 and 89.58 %, respectively) in both seasons. There were significant differences among holding solutions with respect to their ability to reduce stem curvature (%) of gerbera cut flowers. In this concern, the least percent was recorded by solution (A) plus humic acid either at 25 or 50 ml/l solution. Regarding stem curvature (%) as affected by storage periods as presented in Table 1. The results of this work cleared that cold storage of gerbera for 10 days caused more stem curvature when compared with 0-days in both seasons. Concerning the data of interaction (holding solutions x storage periods).The obtained results in Table 1 show that the tested storage periods and holding solutions which significantly lowered stem curvature (%) of gerbera cut flowers and resulted in prolonging the vase life included the storage for 0-days combined with the all holding solutions to reach the highest effect with solution (A) plus humic acid at 25 ml/l followed by solution (A) plus humic acid at 50 ml/l as well as the effect of solution (A) solely which came in the third rank. In gerbera cut flowers a high level of turgidity is necessary for disk florets opening. These results are in accordance with those reported by Madhavi [20] on gerbera cut flowers who pointed out that stem curvature angle after dry storage increased with increasing storage period. The curvature was related to the water potential of the ray petals, which suggests that scape bending is due to a low water potential. Including bacteria in the vase

Table 2: Effect of holding solutions, storage periods and their interactions on flower traits of cut *Gerbera jamesonii* Hook. cv. 'Dalma' during 2012 and 2013 seasons

Treatment	1st season					
	Flower fresh weight increase (%)			Water uptake (cm)3		
	Storage periods					
Holding solutions	0 days	10 days	Mean	0 days	10 days	Mean
Control (D. W)	1.95	1.43	1.69	43.74	34.81	39.28
Humic acid (50 ml/l)	3.15	2.66	2.90	51.34	45.40	48.37
Humic acid (25 ml/l)	3.34	3.03	3.18	52.31	47.60	49.96
Solution(A)*	4.05	3.54	3.79	57.86	51.25	54.56
Humic acid (50 ml/l) +A	4.80	3.96	4.38	63.00	58.65	60.83
Humic acid (25 ml/l) +A	5.65	4.65	5.15	66.15	62.87	64.51
Mean (B)	3.82	3.21	--	55.73	50.10	--
	2nd season					
Control (D. w)	1.77	1.40	1.58	39.46	33.24	36.35
Humic acid (50 ml/l)	3.02	2.42	2.72	48.00	43.22	45.61
Humic acid (25 ml/l)	3.16	3.08	3.12	50.24	46.83	48.53
Solution(A)*	3.89	3.23	3.56	54.00	49.90	51.95
Humic acid (50 ml/l) +A	4.91	3.55	4.23	60.51	55.20	57.85
Humic acid (25 ml/l) +A	5.71	4.47	5.09	64.36	60.44	62.40
Mean (B)	3.74	3.02	--	52.76	48.14	--

LSD 0.05	Flower fresh weight increase (%)			Water uptake (cm^3)		
	Holding solutions (A)	Storage periods (B)	A x B	Holding solutions (A)	Storage periods (B)	A x B
1st season	1.77	1.02	2.51	2.84	1.64	4.01
2nd season	1.82	1.05	2.57	3.00	1.73	4.24

Solution (A)* = silver nitrate (150 mg/l)+ salicylic acid (150 mg/l) +2% sucrose + 8-Hydroxyquinoline citrate (8- HQC 200 mg/l)

water of cut *Gerbera jamesonii* Bolus flowers resulted in an increase in scape curvature depending on the concentration of bacteria in the water which block the xylem conduits, resulting in low turgor but including antibacterial compounds such as silver nitrate in the vase water decreased the number of bent scapes [21]. Jamshidi *et al.* [22] on cut Gerbera flowers demonstrated that salicylic acid significantly decreased bacterial population in the preservative solution and stem curvature. Application of humic acid increases Ca accumulation in the stem of Gerbera and then vase life will be increased and stem bent will be reduced [7].

Flower Fresh Weight Increase (%): Data concerning flower fresh weight increase (%) as affected by storage periods are presented in Table 2. The results cleared that storage period of 0 days (unstored flowers) treatment recorded an increase in the flower fresh weight % when compared to cold storage period of 10 days in both seasons. This decrease in flower fresh weight percentage might be due to water loss during cold storage compared with unstored flowers (0 days). The holding solutions had fluctuative effects on the fresh weight percentages. The flowers held in solution (A) enhanced the flower fresh weight % followed by humic acid at either 25 or 50 ml/l in both seasons. Combining solution (A) plus humic acid either at 25 or 50 ml/l brought about the highest flower fresh weight percentages in both seasons, whereas the lowest percentages were observed with control in both seasons. The results of interaction (holding solutions x storage period) showed that all holding solutions with storage for 0 day followed by 10 days resulted increment in flower fresh weight percentage. In this respect, the utmost high values in this character was the result of treatment of holding flowers in solution of 25 ml/l humic acid x storage at 0 days (unstored flowers) during both seasons. This agreed with the results found by Kazemi *et al.* [6] on carnation cut flowers who found that salicylic acid + sucrose as holding solution increased flowers fresh weight. Madhavi [20] on gerbera cut flowers revealed that flower fresh weight was decreased with increasing period of dry cold storage. Chamani *et al.* [15] on cut Alstroemeria showed that the highest relative fresh mass content was obtained by lower concentrations of humic acid (100 ppm). Humic acid on Gerbera improves food uptake and hormonal effects [7]. Safa *et al.* [11] on *Gerbera jamesonii* L. cv. 'Balance' indicated that the minimum loss of fresh weight was obtained in 20 mg/l silver nanoparticles. Meanwhile, Ansari *et al.* [23] on cut Gerbera flowers mentioned that silver nanoparticles at 5 mg/l + sucrose at 4% + humic acid at 50 mg/l had the greatest flower fresh weight.

Water Uptake: According to data presented in Table 2, it is obvious that the most holding solutions used in this work induced water uptake (cm^3) with various significant differences when compared to control in both seasons. The highest water uptake in the two seasons was however accomplished by solution (A) plus humic acid either at 25 or 50 ml/l followed by solution (A) solely that caused a significant increase in water uptake. Regarding the effect of storage periods, it was observed from Table 2 that storage periods had a significant effect on the water uptake. In this regard, either 0 days or 10 days cold storage increased water uptake to reach the highest effect with 0 days in both seasons. The interaction between holding solutions and storage periods as shown in Table 2 indicated that humic acid at 25 ml/l followed by 50 ml/l led to the highest increment in water uptake from vases along storage periods with its maximum value at 0 days compared to the other treatments and the differences were significant in both seasons. These results coincided with the findings of Khenizy and Zaky [24] on *Polianthus tuberosa* cv. Double, who found that 3 and 5 days cold storage were less efficient than 0-days (unstored flowers) for absorbed water. Acharyya *et al.* [25] on *Gerbera jamesonii* flowers demonstrated that treatment combination of $AgNO_3$ (100 ppm) + sucrose 4% + distilled water as holding solution was the best in increasing the water uptake and thus extension of vase life. Also, Nair *et al.* [2] on *Gerbera jamesonii* concluded that the maximum quantity of holding solution was absorbed in 20 ppm $AgNO_3$+ 6% sucrose treatment and attributed such effect to the fact that the $AgNO_3$ present in the holding solution acted as a biocide inhibiting microbial population that might have resulted in blockage of the vascular tissues. This is in conformity with the findings of Ketsa *et al.* [26] who opined that $AgNO_3$ prevented microbial occlusion of xylem vessels in Dendrobium, thereby enhancing water uptake and increasing longevity of flowers. Kazemi *et al.* [6] on carnation cut flowers found that salicylic acid + sucrose as a holding solution increased water absorption. Alaey *et al.* [27] showed that using salicylic acid (SA) in vase solutions extended vase-life of cut rose flowers by regulating water uptake. Improved water balance may be due to possible germicidal activity of SA as an antimicrobial compound acting by inhibiting vascular blockage and/or positive regulatory role of SA on stomatal closure which regulates the rates of transpiration and increases the water-retaining capacity of leaves and petals. Reddy and Singh [28] reported that the increase in water uptake by pulsing treatments of gladiolus might be due to that the translocated sugars accumulated in flowers increased the osmotic potential and improved the ability of spikes to absorb water. Chamani *et al.* [15] on cut Alstroemeria showed that the highest solution uptake was obtained by a lower concentration of humic acid (100 ppm).

Number of Rows of Disk Florets Open after 14 Days: The data presented in Table 3 indicate that cold storage for 10 days recorded the least No. of rows of disk florets open compared with unstored flowers (0-days) in both seasons. Similar results were reported by Bang *et al.* [29] on *Dianthus barbatus* who found that when flowers were stored at 2°C for 1-2 weeks, the increase in storage duration was accompanied by decreasing of flowering opening. Meanwhile, the holding solutions treatments indicated their superiority over distilled water which had least values of opening disk florets of gerbera. There were differences among humic acid treatments with respect to their ability to open disk florets of gerbera after 14 days of holding. Gerbera cut flowers held in vase solutions containing humic acid either at 25 or 50 ml/l increased the number of rows of disk florets to reach their maximum records with the treatment of humic acid at 25 ml/l plus solution (A) in both seasons. The results of interaction (holding solutions x storage periods) cleared that the highest number of open rows of disk florets was obtained with humic acid at 25 ml/l plus solution (A) along storage periods with the utmost values at 0 days (10.18 and 9.91 rows in the first and second seasons, respectively), followed by humic acid at 50 ml/l plus solution (A) then solution (A). The results were in harmony with the findings of Gupta *et al.* [30] who concluded that sucrose (2%) + $AgNO_3$ (25ppm)+citric acid (75ppm) and sucrose (2%) + 8-HQC (500ppm) is recommended best solution for bud opening and increasing vase life in chrysanthemum.

Table 3: Effect of holding solutions, storage periods and their interactions on flower traits of cut *Gerbera jamesonii* Hook. cv. 'Dalma' during 2012 and 2013 seasons

Treatment	1st season					
	No. of open rows of disk florets after 14 days			Flower diameter(cm)		
	Storage periods					
Holding solutions (A)	0 days	10 days	Mean (A)	0 days	10 days	Mean (A)
Control (D. w)	8.15	7.03	7.59	7.20	6.55	6.87
Humic acid (50 ml/l)	9.00	7.81	8.40	8.2	7.00	7.60
Humic acid (25ml/l)	9.24	8.03	8.63	8.5	7.43	7.96
Solution(A)*	9.50	8.24	8.87	8.73	7.60	8.16
Humic acid (50 ml/l) +A	9. 84	8.61	9.22	9.40	8.00	8.70
Humic acid (25 ml/l) +A	10.18	8. 96	9.57	9.70	8.24	8.97
Mean (B)	9.31	8.11	--	8.62	7.47	--
	2nd season					
Control (D. w)	7.18	6.40	6.79	7.00	6.37	6.68
Humic acid (50 ml/l)	8.82	7.42	8.12	8.00	6.92	7.46
Humic acid (25 ml/l)	9.06	8.08	8.57	8.33	7.12	7.72
Solution(A)*	9.35	8.20	8.77	8.45	7.35	7.90
Humic acid (50 ml/l) +A	9. 89	8. 47	9.18	9.00	7.61	8.30
Humic acid (25 ml/l) +A	9.91	8. 55	9.23	9.42	8.00	8.71
Mean (B)	9.03	7.85	--	8.36	7.22	--

LSD 0.05	No. of open rows of disk florets after 14 days			Flower diameter(cm)		
	Holding solutions (A)	Storage periods (B)	A x B	Holding solutions (A)	Storage periods (B)	A x B
1st season	2.56	1.47	3.62	2.26	1.30	3.19
2nd season	2.51	1.45	3.55	2.54	1.46	3.59

Solution (A)* =Silver nitrate (150 mg/l) + Salicylic acid (150 mg/l) +2% sucrose+ 8-Hydroxyquinoline citrate (8- HQC 200 mg/l)

Flower Diameter: The flower diameter is a suitable index to flower opening and the stem diameter is important factor of flower quality and play important role in flower marketing. As shown in Table 3, the smallest flower diameter was found in control plants in the two seasons. On the other hand, most of holding solutions used in this study significantly improved such trait throughout the different doses, with the superiority of solution (A) plus humic acid at 25 ml/l which gave the widest diameter in both seasons. Moreover, the treatment of solution (A) either solely or combined with humic acid at 50 ml/l also improved this character. Concerning the effect of cold storage x holding solutions, it was shown that control presented the least flower diameter with 6.55 in the 1st season and 6.37 cm in the 2nd one which was less than the other treatments which ranged between 7.00 to 8.24 cm in the 1st season and 6.92 to 8.00 cm in the 2nd one (Table 3). Comparisons of storage periods showed that the flower diameter after cold storage period was less than unstored flowers (0 days). The results of interaction (holding solutions x storage periods) proved that the pronounced effect on flower diameter resulted from flowers held in humic acid either at 25 or 50 ml/l under lab conditions (0 days) in both seasons compared to other treatments. These results are in harmony with those reported by Jamshidi *et al.* [22] on cut Gerbera flowers who pointed out that salicylic acid significantly increased flower diameter. Ansari *et al.* [23] on cut Gerbera flowers stated that silver nanoparticles (5 mg/l) + Sucrose (4%) + humic acid (50 mg/l) increased flower diameter. Zaky and ElZayat [31] on *Dianthus caryophyllus* stated that the flower diameter after the end of cold storage periods (4 and 6 weeks) was less compared to unstored flowers.

Total Sugars % in Flowers: The effect of storage period as shown in Fig. 1 illustrated that the percentage of total sugars was decreased in flowers after cold storage when compared to 0 days (unstored flowers) treatment in both seasons. This may be due to the reduction in respiration and metabolic rate of the flowers during cold storage.

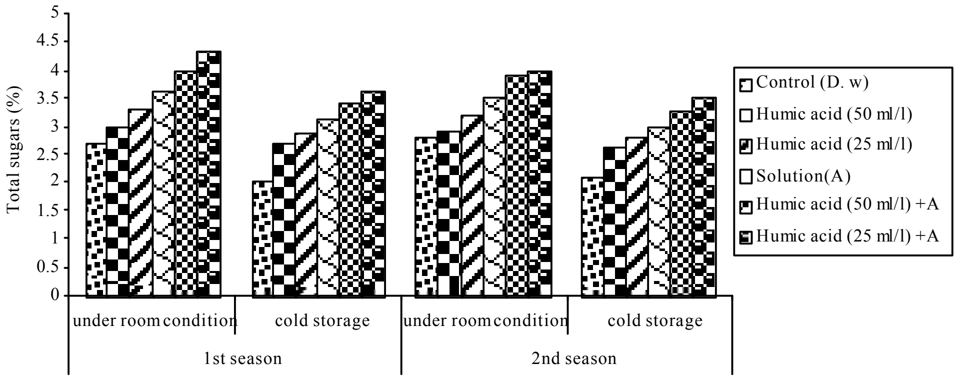

Fig. 1: Effect of holding solutions, storage periods and their interactions on total sugars (%) in cut flowers of *Gerbera jamesonii* Hook. cv. 'Dalma' during 2012 and 2013 seasons.

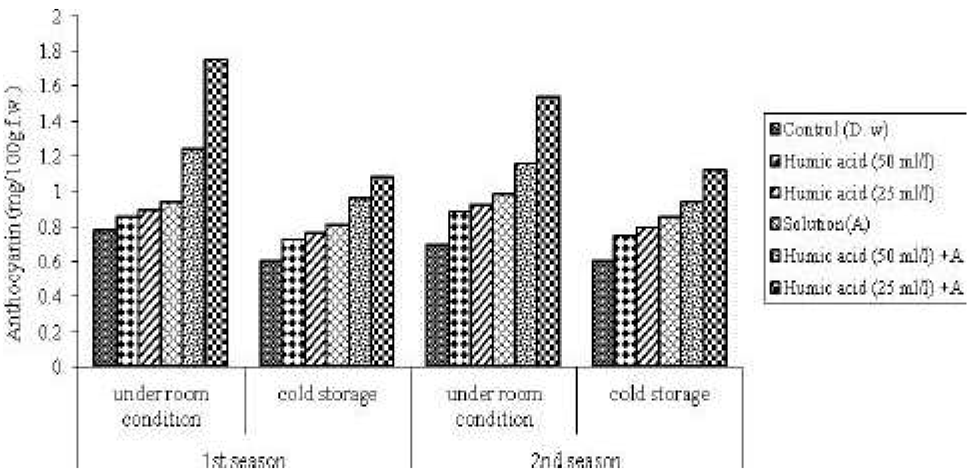

Fig. 2: Effect of holding solutions, storage periods and their interactions on anthocyanin (mg/100g f.w.) in cut flowers of *Gerbera jamesonii* Hook. cv. 'Dalma' during 2012 and 2013 seasons.

Regarding the effect of holding solutions, it was concluded from Fig. 1 that control (D.W) had the least values of total sugars percentage in flowers compared to all other treatments used in the two seasons. Moreover, the highest values of total sugars percentage were found in the flowers held in humic acid at 25 ml/l plus solution (A) followed by humic acid at 50 ml/l plus solution (A) as compared to the other treatments used in both seasons. The interaction effects (holding solutions x storage periods) showed that flowers held in solution (A) plus humic acid either at 25 or 50 ml/l acid were the best for obtaining the highest percentage of total sugars after dry cold storage as compared to the other treatments used under this condition. However, comparisons of storage periods showed that the total sugars percentage in flowers after cold storage period along all holding solutions were less than those unstored flowers (0 days) in both seasons. These results are in line with those obtained by Zamani *et al.* [17] on cut rose flowers who mentioned that salicylic acid reduced chlorophyll total degradation and preserved chlorophyll total content and consequently increased total sugars content. Nano-silver inhibits the respiration and is a key metabolism of electron transfer system and material transfer in microbial cell membrane [32]. Chamani *et al.* [15] on cut Alstroemeria showed that the highest leaf chlorophyll content was obtained by lower concentrations of humic acid. The rate of ethylene production and ethylene induced disorders are greatly reduced at lower storage temperatures which in turn increases the post harvest lasting quality of cut carnation flowers [9].

Anthocyanin Content in Fresh Petals: Data presented in Fig. 2 illustrated that holding freshly harvested Gerbera cut flowers in vase solutions directly after harvesting (0 days) exhibited higher increase in anthocyanin content in flowers than flowers stored at cold storage in the two seasons. In this respect, anthocyanin content in flowers was increased in response to all the used holding solutions comparing with control in the two seasons. However, the mastery was attributed to holding in solution (A) plus humic acid at 25 ml/l. It can be concluded from the interaction between storage periods and holding solutions that treatment of solution (A) either solely or in combination with humic acid and storing for 0 days or 10 days improved anthocyanin content which reached the highest content with solution (A) plus humic acid at 25 ml/l under lab conditions (0 days) when compared to other treatments in the two seasons. In this connection, ShengGen *et al.* [33] pointed out that a solution of 2% sucrose +500 mg citric acid/l + 25 mg $AgNO_3$ /l enhanced anthocyanin content in the petals of *Rosa shinensis* cv. Shenzhenhong. Also, Khenizy [34] on Gladiolus found that spikes placed in a preservative solution consisting of sucrose+ 8-HQS+citric acid improved anthocyanin content under ambient condition compared to those were in cold storage. Kazemi *et al.* [6] on carnation cut flowers found that salicylic acid + sucrose as holding solution significantly decreased anthocyanin leakage.

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