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Improving Quality of *Limonium sinuatum* Cut Flowers with Preservative Solutions and Storage Temperatures

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Abstract: This study was consummated at Postharvest Laboratory of Ornamental Plants and Landscape Gardening Research Dept., Hort. Res. Inst., ARC; Giza, Egypt during 2012 and 2013 seasons to improve quality of *Limonium sinuatum* cut flowers through studying the effect of holding solutions (including distilled water as a control, 0.5ml/l Florissant100 + 200 mg/l 8-hydroxyquinoline citrate, 2% sucrose + 200 mg/l 8-hydroxyquinoline citrate, 2% sucrose + 200 mg/l 8-hydroxyquinoline citrate + 150 mg/l citric acid and 2% sucrose + 200 mg/l 8-hydroxyquinoline citrate + 150 mg/l citric acid + 150 mg/l 6-benzyladenine + 0.5 ml/l Tween20) and storage temperatures including room temperature (21±1°C) or the cold storage at 0 or 5°C for one week, as well as their interactions on longevity and quality of *Limonium sinuatum* cv. Velvet Wings cut flowering stems till the end of vase life. Results indicated that it is recommended to hold the cut flowering stems of *Limonium sinuatum* cv. Velvet Wings in a solution containing 2% sucrose + 200 mg/l 8-hydroxyquinoline citrate + 150 mg/l citric acid + 150 mg/l 6-benzyladenine + 0.5 ml/l Tween20 under room temperature (21±1°C) for prolonging their longevity and improving quality of flowers, followed by cut flowers stored at 0°C and treated with the same previous solution, comparing with the other treatments.

Key words: *Limonium sinuatum* · Preservative solution · Storage temperature · Sucrose · 8-hydroxyquinoline citrate · Citric acid · Florissant100 · Benzyladenine

INTRODUCTION

Limonium sinuatum belongs to the family Plumbaginaceae. It is native of Europe, Mediterranean regions, Asia, the Canary Islands and Africa. It is as a high export and local market value cut flower crop. It is widely used both fresh and dried as filler flower in baskets and other flower arrangements. It is available mainly in blue and purple but currently available in rose, mauve, red, coral, apricot, pale yellow and white colors. The plant is grown in gardens for landscaping borders and rockeries for its crunchy bright and bold flowers. It has long vas life however it blooms in summer when high temperature affects negatively longevity of available cut flowers in this period.

The most important factors that affect the postharvest quality of cut flowers and consequently increase the marketing profits, are freshness and vase life which are highly affected by postharvest handling including holding in preservative solutions and storage temperature. In this respect, Doi and Reid [1] revealed that a vase solution containing 200 ml/ l Physan (a quaternary ammonium disinfectant solution) and 20 g sucrose/l prolonged the longevity and promoted bud opening. The presence of 2% sucrose in the vase solution promoted bud opening and increased the life of cut inflorescences from 5 to 17 days. Immature flower buds developed and opened when 8-HQC was used as a bactericide in *Limonium* cv. Fantasia. Ichimura [2] reported that treating *Limonium* cut flowers cultivar Blue Fantasia 100 with sucrose at 10 and 20 g /l significantly increased the percentage of open florets. Abdel Kader [3] reported that 8-hydroxyquinoline salts delayed senescence of gerbera flowers. Vigna *et al*. [4] reported that 2.5% sucrose +150 mg/ l 8-HQS increased keeping flowers in *Limonium sinuatum*. Yann *et al*. [5] showed that 10% sucrose + 200 ppm 8-HQS prolonged vase life and increases ornamental value of *Limonium*. Ichimura *et al.* [6] mentioned that HQS at 200 ppm combined with sucrose at 20 g/l extended the vase life of

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cut Sonia roses. Kumar and Pal [7] found that rose cultivars First Red and Confetti treated with 8-HQC at 50 ppm gave the maximum vase life (9.88 day). Ibrahim *et al.* [8] found that using solution of 200 ppm 8-HQS plus 4% sucrose significantly increased water uptake of gerbera cut flowers and fresh weight percentage of gerbera cut flowers as compared to distilled water. 200ppm 8-HQS combined with 2% sucrose solution recorded the highest water uptake, water balance, percentage of maximum increase in fresh weight of sweet pea cut flower stems and vase-life and reduced degradation of chlorophyll and carbohydrate [9]. Elgimabi and Sliai [10] showed the a significant improvement in vase life of Taif rose cut flowers was occurred when treated with 200 ppm 8-HQS and the effect was further improved when 8-HQS at 200 ppm combined with 7% sucrose compared to other concentrations of sucrose. Citric acid is advised for a lot of cut flowers like gladiolus [11], gerbera [12] and tuberose [13]. Patil and Reddy [14] found that citric acid in combination with sucrose increased the vase life of *Solidago canedensis.* Vieira *et al.* [15] found that 8-HQC, sucrose and citric acid recorded the longest longevity obtained for snapdragon flowers cv. Potomac White. Devi and Jawaharlal [16] found that BA at 25 ppm + sucrose 2% and 8-HQC 100 ppm + sucrose 2% were the best holding solutions for prolonging the vase life of anthurium. Rudnicki *et al.* [17] stated that the best flower quality of carnations cvs. White Lily Ann and Olenka was achieved when a preservative solution of 200 mg/l HQC + 50 g/l sucrose was used as a continuous treatment following storage at 4°C for 2 weeks. Cool storage (5°C) and rehydration of inflorescences after storage in a sugar solution increased the time that flowers open petals in *Limonium perigrinum* [18]. Cushman *et al*. [19] recorded longest post storage floral longevity and the best flower quality with rose flower stored at 4°C. A reduction in vase life with the increase in temperature of storage was also noticed. Kushal *et al*. [20] stated that pulsing gladiolus cut flower spikes in solution containing 20% sucrose + 200 ppm 8-HQS for 20 h at 23 ± 2°C was more effective than at 5 ± 1°C, since this combined treatment controlled bacterial growth and increased vase life. Ranwala and Miller [21] stated that cold storage of flower stems accelerated leaf chlorosis and reduced inflorescence longevity in Vermeer and Marseille cultivars of cut hybrid lilies. Hettiarachchi and Balas [22] stated that cold storage at 4°C maintained good flower quality during the vase of cut *Kniphofia uvaria* flowers. Ciotta and Nunes [23] mentioned that the longevity of *Limonium sinuatum* cut flowers was longer in solutions containing sucrose stored under room temperature than in cold storage. Waithaka et *al.* [24] pointed out that the vase life and floret opening of tuberose inflorescences were significantly decreased by cold storage. Doorn and Han [25] mentioned that cold storage increases the number of floral buds that fail to open and hastens petal wilting, increases leaf yellowing and promotes bud abscission in lilies and that negative effects of cold storage can be alleviated by sugars and others by gibberellins with or without benzyladenine.

So, our study was to improve quality and to extend display life of *Limonium sinuatum* cv. Velvet Wings cut flowers through assessment preservative solutions and storage temperatures.

MATERIALS AND METHODS

This study was conducted at postharvest laboratory of Ornamental Plants and Landscape Gardening Research Dept., Hort. Res. Inst., ARC; Giza, Egypt in mid March of the two seasons 2012 and 2013. *Limonium sinuatum* cv. Velvet Wings cat flowers were obtained from a local commercial greenhouse farm in Giza, Egypt. The flowering stems were cut in the early morning with the stem length of 80 cm (standard for export), almost fully open flowers and wrapped in Kraft paper in bunches each containing 25 flowers. The flowers were transported under dry conditions to the laboratory within two hours then the stems were rapidly precooling by placing them in cool water for three hours. The precooling is an important postharvest operation, which removes the field heat and greatly improves quality and enhances vase life of cut flowers.

The stems base was recut to about 3 cm. Thereafter, the flowering stems were divided into three groups (45 flowering stems per each group).The first group was held in one of the five holding solutions used for postharvest evaluation including: T1= Distilled water (as a control treatment), T2= 0.5ml/l Florissant 100 + 200 mg/l 8-hydroxyquinoline citrate, T3= 2% sucrose + 200 mg/l 8-hydroxyquinoline citrate, T4= 2% sucrose+ 200 mg/l 8-hydroxyquinoline citrate + 150 mg/L citric acid, T5= 2% sucrose + 200 mg/l 8-Hydroxyquinoline citrate + 150 mg/l citric acid + 150 mg/l 6-benzyladenine + 0.5 ml/l Tween 20 till the end of experiment under the room temperature (21±1°C), 65 -75% RH and continuous light (1000-1500 lux) from white fluorescent lamps. The pH in holding solutions were determined and illustrated in Table (1).

Table 1: pH value of holding solutions used in the two seasons

Holding solutions	pH value
1- Distilled water	6.66
2- 0.5ml/l Florissant 100 + 200 mg/l 8-hydroxyquinoline citrate	5.23
3- 2% sucrose + 200 mg/l 8-hydroxyquinoline citrate	5.34
4- 2 % sucrose + 200 mg/l 8-hydroxyquinoline citrate + 150 mg/L citric acid	3.69
5- 2% sucrose + 200mg/l 8-Hydroxyquinoline citrate + 150 mg/l citric acid + 150mg/l 6-benzyladenine + 0.5 ml/l Tween 20	3.56

The second and third groups of the flowers were bunched (15 flowers per bunch) and wrapped in polyethylene bags (80×20 cm, 130 mμ thickness). After that, flower bags were packed in cardboard boxes (125×33×33cm). Half of them were translocated to storage room at 0°C while the others were translocated to storage room at 5°C, both for 7 days at 80-85% relative humidity. After the end of cold-storage period, flowering stems were held in the same five preservative solutions mentioned above. Each bunch was put in clear glass jars to represent one replicate (three flowering stems/jar representing a holding solution treatment). The experimental layout was factorial in a complete randomized design with two factors (holding solutions and the different storage temperatures) with three replicates per treatment.

Data Recorded: The longevity of *Limonium* cut flowers (day) was determined as the number of days to wilting. Water uptake (g/ inflorescence/ day) and water loss (g/ inflorescence/day) were determined through recording the data every two days in both seasons. The change percentage in inflorescence fresh weight (%) was recorded every two days from the beginning of the treatments. Chlorophyll a, chlorophyll b and carotenoids (mg/100g FW) were determined in fresh leaf samples at the end of longevity and measured according to Saric *et al*. [26]. Anthocyanin content (mg/100g FW) in fresh petals at the end of longevity was determined according to the method described by Fuleki and Francis [27]. Total carbohydrates (%) in petals was colorimetrically assessed as described by Dubois *et al*. [28] at the end of the longevity.

Statistical Analysis: The data were tabulated and subjected to analysis of variance as a factorial experiment using MSTAT-C statistical software, 1989 and the means of various treatments were compared by Duncan's Multiple Range Test at 5% level as indicated by Waller and Duncan [29].

RESULTS

Effect of Holding Solutions, Storage Temperature and Their Interactions On

Longevity (Days): Data presented in Table (2) revealed that the significantly highest vase life of *Limonium sinuatum* cv. Velvet Wings cut inflorescences was obtained with the storage under room temperature (21±1°C) which recording 21.85 and 22.60 days in the first and second seasons, respectively. Cold storage at 0° C or 5°C for 7 days before treated with holding solutions was found to induce a negative effect on vase life of the cut inflorescences. The vase life decreased to 17.26 and 18.46 days for storage at 0°C for 7 days in the first and second seasons, respectively, 14.70 and 15.40 days for storage at 5°C for 7 days, in both seasons respectively.

Regarding the effect of holding solutions treatments on longevity, data presented in Table (3) showed that all treatments gave significantly higher values of the vase life in the two seasons than the control treatment. Data indicated that the fifth holding solution (T5) gave the significantly higher shelf life period (24.59 and 25.19 days in the first and second seasons, respectively) compared with the other treatments. On the other hand, distilled water (control) gave the significantly lowest shelf life period (9.19 and 10.30 days in the first and second seasons, respectively).

Data presented in Table (4) revealed the effect of interaction effect of holding solutions and storage temperature treatments on longevity of *Limonium sinuatum* cv. Velvet Wings cut flowers. In both seasons, the results cleared that the significantly highest longevity values of *Limonium sinuatum* cv. Velvet Wings cut flowers was recorded with T5 holding solution treatment under room temperature (21±1°C).

Under the same holding solutions, the longevity of *Limonium sinuatum* cv. Velvet Wings cut flowers gradually decreased as a result of storing them for 0°C or 5°C for 7 days, respectively as compared to that recorded under room temperature (21±1°C).

Table 2: Effect of storage temperature on longevity (days) of *Limonium sinuatum* cv. Velvet Wings cut flowers during 2012 and 2013 seasons

Storage temperature treatments	First season	Second season
Room temperature (21±1°C)	21.85 a	22.60 a
0°C	17.26 b	18.46 b
5°C	14.70 c	15.40 c

Table 3: Effect of holding solutions on longevity (days) of *Limonium sinuatum* cv. Velvet Wings cut flowers during 2012 and 2013 seasons

Holding solutions treatments	First season	Second season
T1	9.19 e	10.30 e
T2	15.41 d	16.59 d
T3	18.55 c	19.51 c
T4	21.94 b	22.55 b
T5	24.59 a	25.19 a

T1= Distilled water (control),T2= 0.5ml/l Florissant 100 + 200mg/l 8-hydroxyquinoline citrate, T3= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate, T4= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate + 150mg/L citric acid, T5= 2% sucrose + 200mg/l 8-Hydroxyquinoline citrate + 150mg/l citric acid + 150mg/l 6-benzyladenine + 0.5ml/l Tween 20

Table 4: Effect of interaction between storage temperature and holding solutions treatments on longevity (days) of *Limonium sinuatum* cv. Velvet Wings cut flowers during 2012 and 2013 seasons

Storage temperature	Holding solutions	First season	Second season
Room temperature (21±1°C)	T1	11.78 h	13.11 h
	T2	20.00 de	21.11 e
	T3	23.33 c	23.89 cd
	T4	26.12 b	26.78 b
	T5	28.00 a	29.11 a
0°C	T1	8.55 i	10.00 i
	T2	15.00 g	15.44 g
	T3	17.19 f	18.58 f
	T4	20.78 d	21.22 e
	T5	24.78 bc	25.22 bc
5°C	T1	7.22 i	8.67 i
	T2	10.22 h	12.11 h
	T3	15.11 g	15.56 g
	T4	18.93 e	19.19 f
	T5	21.00 d	22.33d e

T1= Distilled water (control), T2= 0.5ml/l Florissant 100 + 200mg/l 8-hydroxyquinoline citrate, T3= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate, T4= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate + 150mg/L citric acid, T5= 2% sucrose + 200mg/l 8-Hydroxyquinoline citrate + 150mg/l citric acid + 150mg/l 6-benzyladenine + 0.5ml/l Tween 20

Under each storage temperature T5 treatment gave the significantly higher longevity values, followed by T4, T3, T2 and T1 (control) treatments, respectively.

The Change Percentage of Fresh Weight (%): Cold storage for 7 days, either at 0° C or 5°C significantly decreased the percentage of change in fresh weight of *Limonium* cut flowers as compared to cut flowers which were stored at room temperature (21±1°C) and recorded the highest change % in the two seasons (Table 5). The changes percentage of fresh weight of cut flowers which were stored at room temperature (21±1°C) increased up to the 13th day in the first season and up to the 11th day in the second season, while *Limonium* cut flowers which were stored at 0°C or 5°C for 7 days increased the percentage of change in fresh weight up to the 11th day in the two seasons. In this concern, Hettiarachchi and Balas [30] reported that the fresh weight change of gloriosa stems was markedly reduced by increasing cold storage temperature and duration.

Data in Table (6) recorded that T5 treatment increased the change percentage of fresh weight of *Limonium sinuatum* cut flowers up to the 13th day of shelf life followed by T4 as compared to other treatments. Similar results were obtained by Abou-Dahab *et al.* [31] who stated that sucrose (2%) + salicylic acid (150 mg/l) + 8-hydroxyqunoline citrate (200 mg/l) was the most effective holding solution for *Nephrolepis exaltata* cut foliage. Also, Solgi *et al.* [32] found that gerbera cut flowers held in 8- hydroxyqunoline citrate (200 mg/l) with different levels of sucrose (4 and 6%) had more fresh weight than the control (distilled water).

Table 5: Effect of storage temperature on the change percentage of fresh weight (%) of *Limonium sinuatum* cv. Velvet Wings cut flowers during 2012 and 2013 seasons

	Day											
Storage temperature treatments	1st	3rd	5th	7th	9th	11st	13th	15th	17th	19th	21st	23rd
	First season: 2012											
Room temperature (21±1°C)	+1.15a	+3.45a	+6.42a	+7.89a	+11.33a	+14.41a	+15.25a	+9.82a	+8.95a	+4.23a	---	---
0°C	+0.83b	+1.44b	+1.87b	+2.22b	+1.92b	+2.73b	+1.92b	+0.87b	-1.31b	---	---	---
5°C	+0.72c	+1.12c	+1.25c	+1.26c	+0.96c	+1.30C	+0.42c	-0.63c	---	---	---	---
	Second season: 2013											
Room temperature (21±1°C)	+0.98a	+3.47a	+6.71a	+7.88a	+11.61a	+14.57a	+9.51a	+9.02a	+43.21a	+4.41a	-2.34a	-2.39a
0°C	+0.86a	+1.48b	+1.90b	+2.27b	+1.93b	+2.93b	+0.91b	-1.12b	10.19b	---	---	---
5°C	+0.77a	+1.15c	+1.28c	+1.31c	+0.95c	+1.33c	-0.52c	-0.66c	3.68c	---	---	---

Table 6: Effect of holding solutions on the change percentage of fresh weight (%) of *Limonium sinuatum* cv. Velvet Wings cut flowers during 2012 and 2013 seasons

	Days											
Holding solution treatments	1st	3rd	5th	7th	9th	11st	13th	15th	17th	19th	21st	23rd
	First season:2012											
T1	+0.59e	+0.96e	+1.39e	-0.87e	-1.46d	---	---	---	---	---	---	---
T2	+0.68d	+1.42d	+2.44d	+2.58d	+3.06c	+2.65d	-0.78e	---	---	---	---	---
T3	+0.81c	+2.05c	+3.17c	+4.59c	+5.04b	+6.50c	+6.78c	-3.51d	-1.65c	---	---	---
T4	+0.99b	+2.49b	+4.03b	+5.88b	+8.14a	+9.68b	+9.81b	+7.34b	+3.42b	---	---	---
T5	+1.42a	+3.07a	+4.85a	+6.77a	+8.89a	+11.34a	+13.51a	+12.94a	+10.95a	+7.06a	---	---
	Second season:2013											
T1	+0.62b	+1.01e	+1.42e	-0.89e	-1.23d	---	---	---	---	---	---	---
T2	+0.70b	+1.46d	+2.48d	+2.58d	+3.08c	+2.76d	-0.92e	-0.70c	---	---	---	---
T3	+0.82b	+2.08c	+3.22c	+4.64c	+5.05b	+7.20c	+6.69c	-3.17d	-1.55d	---	---	---
T4	+0.91b	+2.52b	+4.06b	+5.93b	+8.25a	+9.59b	+9.81b	+7.32b	+3.55b	---	---	---
T5	+1.26a	+3.10a	+4.89a	+6.85a	+9.00a	+11.68a	+13.71a	+13.07a	+11.16a	+7.36a	-3.90a	-3.98a

T1= Distilled water (control), T2= 0.5ml/l Florissant 100 + 200mg/l 8-hydroxyquinoline citrate, T3= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate, T4= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate + 150mg/L citric acid, T5= 2% sucrose + 200mg/l 8-Hydroxyquinoline citrate + 150mg/l citric acid + 150mg/l 6-benzyladenine + 0.5ml/l Tween 20

Limonium cut flowers which were stored under room temperature (21±1°C) and were held in T5 solution treatment achieved the highest values of the change percentage of fresh weight at the 17th day of shelf life (39.44 and 39.11%, in the first and second seasons, respectively), followed by cut flowers which were stored at 0°C for 7 days at the 15th day (6.59 and 6.64%, in both seasons, respectively) and 5°C for 7 days at the 13th day (4.29 and 4.46%, in both seasons, respectively) (Tables 7 and 8).

Water Uptake (g/ Inflorescence/Day): Storage temperature had a marked effect on water uptake as shown in Table (9). Water uptake was increased under room temperature (21±1°C) till the 11th day in both seasons, after that it was decreased. In both seasons, storage *Limonium* cut flowers under room temperature (21±1°C) recorded the highest amount of water uptake at the 11th days by cut flowers (61.07 and 65.27 g/ inflorescence/day, in the first and second seasons, respectively). In the first season, the highest value of water uptake was recorded in the 9th day and 7th day for cut flowers which were stored at 0°C and 5°C, respectively whereas in the second season it recorded the highest values in the 9th day for cut flowers which were stored at 0°C and 5°C, respectively.

Data in Table (10) clearly indicated that, during the same day, T5 holding solution treatment recorded the highest values of water uptake followed by T4, T3, T2 and T1 (control) with significant difference among them. T5 holding solution treatment was the best treatment for increasing water uptake till the 13th day (100.6 g/inflorescence/day) in the first season and 15th day (103.0 g/inflorescence/day) in the second season. These results are in agreement with the results obtained by Abou-Dahab *et al.* [31] who showed that the holding solution containing sucrose (2%) + salicylic acid (150 mg/l) + hydroxyquinoline citrate (200 mg/l) was the best treatment for increasing water uptake in *Nephrolepis exaltata* cut foliage.

Table 7: Effect of interaction between storage temperature and holding solutions treatments on the change percentage of fresh weight (%) of *Limonium sinuatum* cv. Velvet Wings cut flowers during 2012 season

First season 2012									
Storage Temperatures									
	Days								
	1st			3rd			5th		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	+0.77f	+0.57h	+0.42i	+1.11j	+0.96k	+0.82l	+3.34e	+1.13l	-0.28m
T2	+0.85e	+0.66g	+0.52h	+2.24d	+1.07j	+0.97k	+4.84d	+1.29kl	+1.19kl
T3	+0.95d	+0.78f	+0.69g	+3.69c	+1.36h	+1.11j	+6.41c	+1.65ij	+1.45jk
T4	+1.13b	+0.95d	+0.89e	+4.44b	+1.82f	+1.22i	+7.84b	+2.45g	+1.80i
T5	+2.03a	+1.17b	+1.07c	+5.74a	+2.03e	+1.45g	+9.68a	+2.81f	+2.07h
	7th			9th			11th		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	-2.40l	-0.22j	---	-4.36g	---	---	---	---	---
T2	+6.88d	+2.07i	-1.21k	+10.71c	-1.53ef	---	+7.95d	---	---
T3	+9.15c	+2.50g	2.12hi	+13.96b	+3.05d	-1.90f	+17.73c	+3.67g	---
T4	+12.11b	+3.16f	2.37gh	+17.49a	+3.88d	+3.06d	+21.26b	+4.81f	+2.34i
T5	+13.69a	+3.59e	+3.03f	+18.86a	+4.18d	+3.64d	+25.19a	+5.18e	+4.16g
	13th			15th			17th		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	---	---	---	---	---	---	---	---	---
T2	-2.36h	---	---	---	---	---	---	---	---
T3	+21.73c	-1.37g	---	-10.55g	---	---	-4.96d	---	---
T4	+26.56b	+5.06de	-2.19gh	+24.26b	-2.22e	---	+10.27b	---	---
T5	+30.31a	+5.92d	+4.29e	+35.39a	+6.59c	-3.16f	+39.44a	-6.59d	---
	19th			21st			23rd		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	---	---	---	---	---	---	---	---	---
T2	---	---	---	---	---	---	---	---	---
T3	---	---	---	---	---	---	---	---	---
T4	---	---	---	---	---	---	---	---	---
T5	+21.18a	---	---	---	---	---	---	---	---

T1= Distilled water (control), T2= 0.5ml/l Florissant 100 + 200mg/l 8-hydroxyquinoline citrate, T3= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate, T4= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate + 150mg/L citric acid, T5= 2% sucrose + 200mg/l 8-Hydroxyquinoline citrate + 150mg/l citric acid + 150mg/l 6-benzyladenine + 0.5ml/l Tween 20

The results of the effect of storage temperatures and holding solutions treatments on the water uptake by *Limonium sinuatum* cv. Velvet Wings are shown in Tables (11 and 12). In both seasons, the data stated that keeping *Limonium sinuatum* cv. Velvet Wings cut flowers under room temperature (21±1°C) in T5 solution increased water uptake more than the other treatments till the 17th day, followed by storing flowers at 0°C for 7 days in the same holding solution which increased water uptake till the 15th day in the two seasons. These results coincided with the finding of Abd-Allah *et al.* [33] on Asiatic hybrid lily Orange Tycoon cut flowering stems.

Water Loss (g/Inflorescence/Day): Data shown in Table (13) indicated that, in both seasons, water loss of *Limonium sinuatum* cut flowers which were stored under room temperature (21±1°C) was increased till the 13th day, whereas the water loss of cut flowers which were stored

Table 8: Effect of interaction between storage temperature and holding solutions treatments on the change percentage of fresh weight (%) of *Limonium sinuatum* cv. Velvet Wings cut flowers during 2013 season

Second season 2013									
Storage Temperatures									
	Days								
	1st			3rd			5th		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	+0.80a-d	+0.59b-d	+0.47d	+1.15j	+1.02k	+0.87l	+3.37e	+1.16l	-0.25m
T2	+0.84a-d	+0.68b-d	+0.57cd	+2.26d	+1.11j	+1.00k	+4.88d	+1.32kl	+1.24l
T3	+0.90a-d	+0.79b-d	+0.73b-d	+3.72c	+1.38h	+1.13j	+6.52c	+1.67ij	+1.47jk
T4	+0.97a-d	+0.98a-d	+0.91a-d	+4.47b	+1.83f	+1.27i	+7.86b	+2.50j	+1.83i
T5	+1.41a	+1.24ab	+1.13a-c	+5.77a	+2.07e	+1.48g	+9.71a	+2.84f	+2.13h
	7th			9th			11th		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	-2.49l	-0.91j	---	-3.71h	---	---	---	---	---
T2	+6.81d	+2.11i	-1.17k	+10.97d	-1.72g	-3.04f	+8.02d	-2.05j	---
T3	+9.17c	+2.55g	+2.21hi	+14.18c	+3.13e	-2.14g	+17.82c	+3.77h	-2.89f
T4	+12.17b	+3.22f	+2.41gh	+17.56b	+4.03e	+3.16e	+21.48b	+4.88f	+2.43i
T5	+13.76a	+3.66e	+3.15f	+19.04a	+4.22e	+3.74e	+25.50a	+5.30e	+4.23g
	13th			15th			17th		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	---	---	---	---	---	---	---	---	---
T2	-2.77g	---	---	-2.11e	---	---	---	---	---
T3	+21.97c	-1.88g	---	-9.51f	---	---	-4.66d	---	---
T4	+26.61b	+5.17de	-2.34g	+24.04b	-2.08e	---	+10.67b	---	---
T5	+30.68a	+5.99d	+4.46e	+35.17a	+6.64c	-2.60e	+39.11a	-5.62d	-2.83c
	19th			21st			23rd		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	---	---	---	---	---	---	---	---	---
T2	---	---	---	---	---	---	---	---	---
T3	---	---	---	---	---	---	---	---	---
T4	---	---	---	---	---	---	---	---	---
T5	+22.10a	---	---	-11.70a	---	---	-11.96a	---	---

T1= Distilled water (control), T2= 0.5ml/l Florissant 100 + 200mg/l 8-hydroxyquinoline citrate, T3= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate, T4= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate + 150mg/L citric acid, T5= 2% sucrose + 200mg/l 8-Hydroxyquinoline citrate + 150mg/l citric acid + 150mg/l 6-benzyladenine + 0.5ml/l Tween 20

Table 9: Effect of storage temperature on water uptake (g/ inflorescence/day) of *Limonium sinuatum* cv. Velvet Wings cut flowers during 2012 and 2013 seasons

	Days											
Storage temperature treatments	1st	3rd	5th	7th	9th	11st	13th	15th	17th	19th	21st	23rd
First season: 2012												
Room temperature(21±1°C)	22.15a	34.42a	47.55a	54.22a	58.99a	61.07a	55.93a	57.68a	48.88a	10.11a	---	---
0°C	18.02b	30.45b	42.80b	48.28b	50.80b	44.66b	36.39b	31.14b	12.03b	---	---	---
5°C	14.21c	28.19c	37.15c	44.31c	41.24c	29.54c	14.51c	8.91c	---	---	---	---
Second season: 2013												
Room temperature (21±1°C)	22.82a	34.70a	48.15a	57.24a	61.54a	65.27a	64.89a	61.64a	43.21a	23.22a	12.91a	5.25a
0°C	19.04b	30.82b	43.83b	50.85b	51.87b	50.45b	46.48b	36.06b	10.19b	---	---	---
5°C	14.94c	29.18c	37.47c	45.91c	47.47c	36.71c	25.52c	12.58c	3.68c	---	---	---

Table 10: Effect of holding solutions on water uptake (g/ inflorescence/day) of *Limonium sinuatum* cv. Velvet Wings cut flowers during 2012 and 2013 seasons

	Days											
Holding solutions treatments	1st	3rd	5th	7th	9th	11st	13th	15th	17th	19th	21st	23rd
	First season:2012											
T1	9.38e	19.41e	20.83e	6.27e	1.00e	---	---	---	---	---	---	---
T2	14.44d	25.58d	38.70d	50.28d	34.07d	16.47d	2.33d	---	---	---	---	---
T3	17.75c	29.61c	42.98c	54.94c	65.75c	45.80c	19.74c	21.15c	9.33c	---	---	---
T4	23.13b	36.53b	51.05b	60.55b	69.96b	74.75b	55.44b	46.43b	29.11b	---	---	---
T5	25.93a	44.01a	58.97a	72.57a	80.94a	88.41a	100.6a	95.47a	63.08a	16.85a	---	---
	Second season:2013											
T1	9.74e	19.65e	21.20e	14.62e	3.78e	---	---	---	---	---	---	---
T2	15.40d	26.04d	38.80d	51.38d	43.53d	30.47d	10.25d	3.68d	---	---	---	---
T3	18.69c	30.49c	43.94c	56.04c	67.28c	59.65c	45.03c	22.21c	6.21c	---	---	---
T4	23.76b	36.76b	51.72b	61.46b	71.15b	74.14b	77.26b	54.89b	24.99b	---	---	---
T5	27.13a	44.89a	60.07a	73.16a	82.39a	89.80a	95.61a	103.0a	63.92a	38.71a	21.52a	8.74a

T1=Distilled water (control), T2= 0.5ml/l Florissant 100 + 200mg/l 8-hydroxyquinoline citrate, T3= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate, T4= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate + 150mg/L citric acid, T5= 2% sucrose + 200mg/l 8-Hydroxyquinoline citrate + 150mg/l citric acid + 150mg/l 6-benzyladenine + 0.5ml/l Tween 20

Table 11: Effect of interaction between storage temperature and holding solutions treatments on water uptake (g/ inflorescence/day) of *Limonium sinuatum* cv. Velvet Wings cut flowers during 2012 season

First season 2012									
Storage Temperatures									
`	Days								
	1st			3rd			5th		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	11.65i	8.66j	7.83j	22.11h	18.79i	17.32j	31.50g	26.52h	4.45i
T2	17.48g	14.29h	11.56i	29.56f	24.62g	22.56h	42.28e	37.54f	36.28f
T3	21.28de	18.42fg	13.55hi	34.67e	28.45f	25.67g	45.9de	42.33e	41.33e
T4	28.44b	22.44d	18.52fg	38.51d	35.91e	35.17e	54.29b	50.58c	48.26cd
T5	31.90a	26.30c	19.60ef	47.26a	44.50b	40.26c	64.41a	57.05b	55.45b
	7th			9th			11th		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	14.33g	4.49h	---	3.00h	---	---	---	---	---
T2	55.47d	49.91e	45.47f e	61.56f	40.65g	---	49.40g	---	---
T3	58.73d	55.20d	50.88d	69.62d	65.19e	62.45f	78.06d	59.35f	---
T4	65.78c	59.08d	56.78d	74.29c	68.64d	66.96de	83.44c	77.46d	63.35e
T5	76.78a	72.50b	68.44c	86.48a	79.51b	76.82c	94.44a	86.47b	84.33c
	13th			15th			17th		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	---	---	---	---	---	---	---	---	---
T2	7.00d	---	---	---	---	---	---	---	---
T3	59.22c	---	---	63.45c	---	---	28.00d	---	---
T4	94.90ab	71.41bc	---	101.4b	37.90d	---	87.33b	---	---
T5	118.6a	110.5a	72.56bc	123.6a	118.3a	44.56d	129.1a	60.17c	---
	19th			21st			23rd		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	---	---	---	---	---	---	---	---	---
T2	---	---	---	---	---	---	---	---	---
T3	---	---	---	---	---	---	---	---	---
T4	---	---	---	---	---	---	---	---	---
T5	50.56a	---	---	---	---	---	---	---	---

T1= Distilled water (control), T2= 0.5ml/l Florissant 100 + 200mg/l 8-hydroxyquinoline citrate, T3= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate, T4= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate + 150mg/L citric acid, T5= 2% sucrose + 200mg/l 8-Hydroxyquinoline citrate + 150mg/l citric acid + 150mg/l 6-benzyladenine + 0.5ml/l Tween 20

Table 12: Effect of interaction between storage temperature and holding solutions treatments on water uptake (g/ inflorescence/day) of *Limonium sinuatum* cv. Velvet Wings cut flowers during 2013 season

Second season 2013									
Storage Temperatures									
	Days								
	1st			3rd			5th		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	12.03i	9.50j	7.68j	22.10i	19.29j	17.56j	32.00h	26.59i	5.00j
T2	17.89fg	16.54g	11.78i	29.89f	24.47h	23.78hi	42.00ef	38.40fg	36.01gh
T3	21.80d	19.61ef	14.67h	34.93e	29.67f	26.86g	45.63de	43.78de	42.41ef
T4	28.90b	23.27d	19.12f	38.63d	36.04e	35.59e	54.66b	52.48c	48.03d
T5	33.49a	26.46c	21.44de	47.96a	44.61b	42.11c	66.44a	57.89b	55.89bc
	7th			9th			11th		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	25.27g	14.11h	4.48i	11.33h	---	---	---	---	---
T2	56.14de	51.44ef	46.55f	62.20e	41.78f	26.61g	67.30b-d	24.11e	---
T3	60.45cd	55.45de	52.23ef	71.11b-e	66.85c-e	63.89de	79.61a-c	62.16cd	37.20e
T4	66.59bc	60.41cd	57.37de	75.74a-d	69.54b-e	68.16c-e	83.78ab	77.94a-d	60.71d
T5	77.74a	72.82ab	68.93b	87.30a	81.16ab	78.72a-c	95.66a	88.07a	85.67ab
	13th			15th			17th		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	---	---	---	---	---	---	---	---	---
T2	30.74e	---	---	11.05d	---	---	---	---	---
T3	88.63bc	46.45d	---	66.63c	---	---	18.63c	---	---
T4	93.64b	88.08bc	50.23d	105.3b	59.38c	---	74.98b	---	---
T5	111.6a	97.85bc	77.39c	125.2a	120.9a	62.90c	122.40a	50.96c	18.39c
	19th			21st			23rd		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	---	---	---	---	---	---	---	---	---
T2	---	---	---	---	---	---	---	---	---
T3	---	---	---	---	---	---	---	---	---
T4	---	---	---	---	---	---	---	---	---
T5	116.1a	---	---	64.56a	---	---	26.23a	---	---

T1= Distilled water (control),T2= 0.5ml/l Florissant 100 + 200mg/l 8-hydroxyquinoline citrate, T3= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate, T4= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate + 150mg/L citric acid, T5= 2% sucrose + 200mg/l 8-Hydroxyquinoline citrate + 150mg/l citric acid + 150mg/l 6-benzyladenine + 0.5ml/l Tween 20

Table 13: Effect of storage temperature on water loss (g/ inflorescence/day) of *Limonium sinuatum* cv. Velvet Wings cut flowers during 2012 and 2013 seasons

	Day											
Storage temperature treatments	1st	3rd	5th	7th	9th	11st	13th	15th	17th	19th	21st	23rd
First season: 2012												
Room temperature (21±1°C)	7.39c	20.34c	33.07b	45.61b	50.06a	51.77a	55.39a	52.93a	39.73a	10.27a	---	---
0°C	8.38b	22.70b	39.98a	44.68b	50.26a	44.22b	37.23b	30.45b	14.81b	---	---	---
5°C	12.50a	26.06a	37.10ab	52.27a	43.71b	30.20c	19.59c	11.28c	---	---	---	---
Second season: 2013												
Room temperature (21±1°C)	9.03c	22.18c	34.92c	44.30b	51.01b	56.66a	57.01a	56.54a	40.82a	15.85a	8.25a	3.30a
0°C	10.85b	24.55b	38.37b	47.71b	51.79b	48.82b	44.13b	35.39b	10.43b	---	---	---
5°C	9.03c	27.33a	42.35a	50.22a	52.97a	38.24c	24.66c	11.74c	3.57b	---	---	---

Table 14: Effect of holding solutions on water loss (g/ inflorescence/day) of *Limonium sinuatum* cv. Velvet Wings cut flowers during 2012 and 2013 seasons

	Day											
Holding solution treatments	1st	3rd	5th	7th	9th	11st	13th	15th	17th	19th	21st	23rd
First season:2012												
T1	5.07e	14.63e	20.86e	13.32d	1.19e	---	---	---	---	---	---	---
T2	7.11d	17.28d	31.97d	45.30c	29.59d	16.44.d	8.52d	---	---	---	---	---
T3	9.129c	20.98c	36.93c	51.89bc	63.85c	42.42c	30.14c	21.77c	3.95c	---	---	---
T4	11.41b	26.10b	43.04b	58.11b	68.28b	65.50b	58.48b	44.11b	22.14b	---	---	---
T5	14.40a	36.18a	50.79a	68.99a	77.14a	85.96a	89.88a	91.88.a	64.81a	17.2a	---	---
Second season:2013												
T1	6.81e	15.72e	22.38e	12.17e	3.35d	---	---	---	---	---	---	---
T2	9.44d	18.79d	34.00d	74.27d	40.88c	23.87d	9.05d	3.98d	---	---	---	---
T3	11.43c	22.95c	38.93c	53.43c	65.81b	54.42c	41.30c	22.64c	4.29c	---	---	---
T4	13.12b	327.77b	44.93b	58.16b	70.55b	72.87b	69.94b	52.22b	22.97b	---	---	---
T5	15.90a	38.21a	52.68a	71.05a	79.00a	88.37a	89.36a	93.93a	63.82a	26.42a	13.76a	5.51a

T1=Distilled water (control), T2= 0.5ml/l Florissant 100 + 200mg/l 8-hydroxyquinoline citrate, T3= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate, T4= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate + 150mg/L citric acid, T5= 2% sucrose + 200mg/l 8-Hydroxyquinoline citrate + 150mg/l citric acid + 150mg/l 6-benzyladenine + 0.5ml/l Tween 20

at 0°C for 7 days increased till the 11th day. The water loss of cut flowers that were stored at 5°C for 7 days increased till the 7th day in the first season and till the 9th day in the second season.

Data presented in Table (14) showed that all holding solutions significantly increased water loss by *Limonium* cut flowers, as compared to the control. The highest record in this concern belonged to cut flowers that were kept in T5 till the 15th day in both seasons.

It is evident from the data presented in Tables (15 and 16) that, in both seasons, water loss of *Limonium sinuatum* cv. Velvet Wings cut flowers that were held in T5 solution treatment was higher than the other values recorded for cut flowers that were held in other solutions under the same temperature. In most cases, water loss of *Limonium sinuatum* cv. Velvet Wings cut flowers treated with all holding solutions and were stored under room temperature (21±1°C) was lower than that values recorded with cut flowers that were stored at 0°C or 5°C for 7 days. The previous results are in agreement with the result obtained by Khenizy [34] on gladiolus spikes.

Chlorophyll a, Chlorophyll b and Carotenoids (mg/100 g FW): According to the data presented in Table (17), it can be concluded that *Limonium* cut flowers which were stored under room temperature (21±1°C) gave the highest means of the leaf content of chlorophyll a, chlorophyll b and carotenoids content as compared with that recorded with cut flowers stored at 0°C and 5°C for 7 days in both seasons. T5 holding solution retarded the degradation of chlorophyll a and chlorophyll b of *Limonium* cut flowers. So, cut flowers treated with T5 holding solution gave the highest chlorophyll a and chlorophyll b contents in leaves, as compared to the values recorded with cut flowers that were held in other holding solutions. On the other hand, cut flowers treated with T5 holding solution gave the lowest carotenoids content.

Data shown in Table (18) revealed that, in both seasons, within each storage temperature the leaves of *Limonium* cut flowers which were held in T5 holding solution gave the highest chlorophyll a and b followed by T4, T3, T2 and T1 (control). The carotenoids content showed opposite trend to that previous trend. Room temperature (21±1°C) proved to be the suitable storage temperature as compared to 0 °C and 5 °C under the same holding solution since it decreased the degradation of chlorophyll a and b in leaves of *Limonium* cut flowers. The highest contents of chlorophyll a and chlorophyll b as well as the lowest contents of carotenoids were recorded by holding *Limonium* cut flowers in T5 under room temperature (21±1°C).

Anthocyanin Content (mg/100g FW): Data illustrated in Table (19) showed that anthocyanin content (mg/100g FW) in petals of *Limonium* cut flowers which were stored under room temperature (21±1°C) recorded the highest value as compared with those stored at 0°C and 5°C, respectively for 7 days in both seasons.

Data presented in Table (20) revealed that, in both seasons, the significantly highest contents of anthocyanin recorded with *Limonium* cut flowers treated with T5 holding solution. *Limonium* cut flowers treated with T5 and were stored under room temperature (21±1°C) recorded the highest anthocyanin content, compared with other *Limonium* cut flowers which were held in different solutions under various storage temperatures.

Table 15: Effect of interaction between storage temperature and holding solutions treatments on water loss (g/ inflorescence/day) of *Limonium sinuatum* cv. Velvet Wings cut flowers during 2012 season

First season 2012									
Storage Temperatures									
	Days								
	1st			3rd			5th		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	3.95i	4.79i	6. 47gh	12.74k	14.94j	16.21ij	26.57h	29.52gh	6.50i
T2	5.32hi	6.55gh	9.45de	14.95j	17.42hi	19.47fg	28.91gh	32.67fg	34.32e-g
T3	7.02g	7.77fg	12.59c	18.83gh	20.63ef	23.49d	32.86fg	38.76cd	39.17c-e
T4	8.69ef	10.32d	15.22b	21.70e	24.35d	32.26c	36.21d-f	42.58c	50.34b
T5	11.99c	12.48c	18.74a	33.48c	36.17b	38.88a	40.84cd	56.38a	55.19ab
	7th			9th			11th		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	17.70f	5.11f	---	3.56i	---	---	---	---	---
T2	41.71e	42.91e	51.29c-e	47.40g	41.36h	---	49.31d	---	---
T3	48.53de	51.53c-e	55.60b-e	60.19f	63.81e	67.54cd	67.69bc	59.57cd	---
T4	54.62b-e	55.36b-e	64.35a-d	64.64de	68.52c	71.67b	59.38cd	75.50ab	61.60b-d
T5	65.50a-c	68.50ab	72.97a	74.51b	77.59a	79.33a	82.47a	86.01a	89.40a
	13th			15th			17th		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	---	---	---	---	---	---	---	---	---
T2	25.57b	---	---	---	---	---	---	---	---
T3	78.26a	---	---	65.30c	---	---	11.85c	---	---
T4	84.52a	77.48a	---	91.71b	40.60d	---	66.43b	---	---
T5	88.60a	96.51a	84.52a	107.60a	111.60a	56.40c	120.40a	74.07b	---
	19th			21st			23rd		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	---	---	---	---	---	---	---	---	---
T2	---	---	---	---	---	---	---	---	---
T3	---	---	---	---	---	---	---	---	---
T4	---	---	---	---	---	---	---	---	---
T5	51.37a	---	---	---	---	---	---	---	---

T1= Distilled water (control), T2= 0.5ml/l Florissant 100 + 200mg/l 8-hydroxyquinoline citrate, T3= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate, T4= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate + 150mg/L citric acid, T5= 2% sucrose + 200mg/l 8-Hydroxyquinoline citrate + 150mg/l citric acid + 150mg/l 6-benzyladenine + 0.5ml/l Tween 20

Total Carbohydrates Percentage (%): Data presented in Table (21) showed the effect of storage temperatures on total carbohydrates percentage in petals of *Limonium sinuatum* cv. Velvet Wings cut flowers during two seasons. Data revealed that the percentage of total carbohydrates was decreased in *Limonium* cut flowers which were stored at 0°C (34.97 and 36.66% in the first and second seasons respectively) and 5°C (26.42 and 27.70 %, in both seasons, respectively) for 7 days as compared to storing cut flowers under room temperature (21±1°C) which resulted in the highest total carbohydrates percentage (45.12 and 46.79%) in the first and second seasons, respectively.

Data shown in Table (22) revealed that, in both seasons, *Limonium* cut flowers which were held in various preservative solutions recorded significantly higher percentage of total carbohydrates in petals as compared with values recorded with the flowers that were held in distilled water (control). *Limonium* cut flowers which were held in T5 solution recorded the significantly highest total carbohydrate percentage.

Table 16: Effect of interaction between storage temperature and holding solutions treatments on water loss (g/ inflorescence/day) of *Limonium sinuatum* cv. Velvet Wings cut flowers during 2013 season

Second season 2013									
Storage Temperatures									
	Days								
	1st			3rd			5th		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	5.34h	7.44g	7.66g	14.52h	15.97g	16.66g	28.24g	32.07fg	6.87h
T2	7.17g	9.22ef	11.93d	17.25g	18.99f	20.13ef	31.11fg	35.25ef	35.63ef
T3	8.57fg	11.04d	14.68c	20.60e	22.65d	25.60c	34.78ef	40.73cd	40.70cd
T4	10.50de	12.00d	16.87b	23.37d	25.85c	34.10b	38.48de	44.40c	51.91b
T5	13.55c	14.52c	19.64a	35.18b	39.30a	40.15a	42.01cd	59.30a	56.73ab
	7th			9th			11th		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	19.10h	12.64i	4.78j	10.07g	---	---	---	---	---
T2	44.67g	45.07g	52.06ef	49.25e	43.67e	29.72f	50.93ef	20.67g	---
T3	49.46fg	53.47ef	57.36de	62.53d	65.56cd	69.34b-d	69.36b-d	56.21de	37.69f
T4	56.40de	56.71de	61.38cd	66.68cd	70.51a-d	74.47a-c	78.44a-c	77.78a-c	62.39c-e
T5	66.98bc	70.67ab	75.51a	76.31a-c	79.19ab	81.51a	84.58ab	89.42a	91.12a
	13th			15th			17th		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	---	---	---	---	---	---	---	---	---
T2	27.18d	---	---	11.95d	---	---	---	---	---
T3	80.32b	43.59c	---	67.92c	---	---	12.63c	---	---
T4	86.77ab	81.53b	41.52c	93.18b	63.49c	---	68.92b	---	---
T5	90.79ab	95.54a	81.76b	109.60a	113.40a	58.71c	122.50a	52.13b	16.79c
	19th			21st			23rd		
Holding solutions	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C	(21±1°C)	0°C	5°C
T1	---	---	---	---	---	---	---	---	---
T2	---	---	---	---	---	---	---	---	---
T3	---	---	---	---	---	---	---	---	---
T4	---	---	---	---	---	---	---	---	---
T5	79.25a	---	---	41.28a	---	---	16.54a	---	---

T1= Distilled water (control), T2= 0.5ml/l Florissant 100 + 200mg/l 8-hydroxyquinoline citrate, T3= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate, T4= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate + 150mg/L citric acid, T5= 2% sucrose + 200mg/l 8-Hydroxyquinoline citrate + 150mg/l citric acid + 150mg/l 6-benzyladenine + 0.5ml/l Tween 20

Table 17: Effect of storage temperature and holding solutions on chlorophyll a, chlorophyll b and carotenoids (mg/100g FW) of *Limonium sinuatum* cv. Velvet Wings leaves during 2012 and 2013 seasons

	First season			Second season		
Treatments	Chl. a	Chl. b	Caro.	Chl. a	Chl. b	Caro.
	Storage temperature					
Room temperature (21±1°C)	0.65a	0.28a	0.53a	0.68a	0.30a	0.55a
0°C	0.39a	0.21b	0.48a	0.42a	0.23a	0.50a
5°C	0.35a	0.20c	0.45a	0.78 a	0.22a	0.48a
	Holding solution					
T1	0.29a	0.13e	0.70a	0.32a	0.15a	0.77a
T2	0.33a	0.16d	0.57a	0.36a	0.18a	0.59ab
T3	0.43a	0.21c	0.49a	0.45a	0.23a	0.52bc
T4	0.55a	029b	0.37a	0.56a	0.28a	0.39cd
T5	0.73a	0.36a	0.29a	0.76a	0.38a	0.31d

T1= Distilled water (control), T2= 0.5ml/l Florissant 100 + 200mg/l 8-hydroxyquinoline citrate, T3= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate, T4= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate + 150mg/L citric acid, T5= 2% sucrose + 200mg/l 8-Hydroxyquinoline citrate + 150mg/l citric acid + 150mg/l 6-benzyladenine + 0.5ml/l Tween 20

Table 18: Effect of interaction between storage temperature and holding solutions treatments on chlorophyll a, chlorophyll b and carotenoids (mg/100g FW) of *Limonium sinuatum* cv. Velvet Wings leaves during 2012 and 2013 seasons

Storage temperature	Holding solutions	Chl. a	Chl. b	Caro.
	First season			
Room temperature (21±1°C)	T1	0.34bc	0.16f-h	0.78a
	T2	0.39bc	0.22ef	0.54ab
	T3	0.58bc	0.24de	0.49ab
	T4	0.76b	0.32bc	0.34ab
	T5	1.19a	0.45a	0.25b
0°C	T1	0.28bc	0.12h	0.69ab
	T2	0.31bc	0.14h	0.60ab
	T3	0.37bc	0.20ef	0.53ab
	T4	0.48bc	0.28cd	0.45ab
	T5	0.51bc	0.34cd	0.37ab
5°C	T1	0.24c	0.11h	0.65ab
	T2	0.28bc	0.13gh	0.57ab
	T3	0.33bc	0.19e-g	0.46ab
	T4	0.40bc	0.27cd	0.33ab
	T5	0.49bc	0.31bc	0.26b
	Second season			
Room temperature (21±1°C)	T1	0.38bc	0.20e-i	0.81a
	T2	0.44bc	0.24d-f	0.56bc
	T3	0.60bc	0.27c-e	0.50cd
	T4	0.78b	0.33bc	0.35de
	T5	1.22a	0.47a	0.28e
0°C	T1	0.30c	0.14hi	0.71ab
	T2	0.35bc	0.15g-i	0.62bc
	T3	0.41bc	0.23d-g	0.58bc
	T4	0.50bc	0.24d-g	0.47cd
	T5	0.55bc	0.36b	0.39de
5°C	T1	0.27c	0.12i	0.66b
	T2	0.30c	0.16f-i	0.60bc
	T3	0.35bc	0.21e-h	0.48cd
	T4	0.42bc	0.30b-d	0.35de
	T5	0.52bc	0.33bc	0.28e

T1= Distilled water (control), T2= 0.5ml/l Florissant 100 + 200mg/l 8-hydroxyquinoline citrate, T3= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate, T4= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate + 150mg/L citric acid, T5= 2% sucrose + 200mg/l 8-Hydroxyquinoline citrate + 150mg/l citric acid + 150mg/l 6-benzyladenine + 0.5ml/l Tween 20

Table 19: Effect of storage temperature and holding solutions on anthocyanin content (mg/100g FW) of *Limonium sinuatum* cv. Velvet Wings leaves during 2012 and 2013 seasons

	First season	Second season
	Storage temperature treatments	
Under room temperature	1.80a	1.75a
0°C	1.44b	1.46b
5°C	1.13c	1.16c
	Holding solutions treatments	
T1	0.79e	0.81e
T2	1.10d	0.14d
T3	1.33c	1.35c
T4	1.65b	1.71b
T5	2.42a	2.26a

T1= Distilled water (control), T2= 0.5ml/l Florissant 100 + 200mg/l 8-hydroxyquinoline citrate, T3= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate, T4= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate + 150mg/L citric acid, T5= 2% sucrose + 200mg/l 8-Hydroxyquinoline citrate + 150mg/l citric acid + 150mg/l 6-benzyladenine + 0.5ml/l Tween 20

Table 20: Effect of interaction between storage temperature and holding solutions treatments on anthocyanin content (mg/100g FW) of *Limonium sinuatum* cv. Velvet Wings leaves during 2012 and 2013 seasons

Storage temperature	Holding Solutions	First season	Second season
Room temperature (21±1°C)	T1	1.02g	1.04g
	T2	1.27f	1.32ef
	T3	1.49de	1.50de
	T4	2.05c	2.17c
	T5	3.18a	2.68a
0°C	T1	0.77h	0.81h
	T2	1.03g	1.06g
	T3	1.33ef	1.34ef
	T4	1.66d	1.69d
	T5	2.41b	2.42b
5°C	T1	0.56i	0.58i
	T2	1.00g	1.04g
	T3	1.17f-g	1.21fg
	T4	1.23f	1.27f
	T5	1.68d	1.69d

T1= Distilled water (control), T2= 0.5ml/l Florissant 100 + 200mg/l 8-hydroxyquinoline citrate, T3= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate, T4= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate + 150mg/L citric acid, T5= 2% sucrose + 200mg/l 8-Hydroxyquinoline citrate + 150mg/l citric acid + 150mg/l 6-benzyladenine + 0.5ml/l Tween 20

Table 21: Effect of storage temperature and holding solutions on total carbohydrates (%) of *Limonium sinuatum* cv. Velvet Wings during 2012 and 2013 seasons

Treatments	First season	Second season
	Storage temperature treatments	
Room temperature (21±1°C)	45.12a	46.79a
0°C	34.97b	36.66b
5°C	26.42c	27.70c
	Holding solutions treatments	
T1	19.42e	20.20e
T2	28.27 d	30.51d
T3	36.83c	38.35c
T4	43.52b	45.19b
T5	49.48a	51.01a

T1= Distilled water (control), T2= 0.5ml/l Florissant 100 + 200mg/l 8-hydroxyquinoline citrate, T3= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate, T4= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate + 150mg/L citric acid, T5= 2% sucrose + 200mg/l 8-Hydroxyquinoline citrate + 150mg/l citric acid + 150mg/l 6-benzyladenine + 0.5ml/l Tween 20

Table 22: Effect of interaction between storage temperature and holding solutions treatments on total carbohydrates (%) of *Limonium sinuatum* cv. Velvet Wings during 2012 and 2013 seasons

Storage temperature	Holding solutions	First season	Second season
Room temperature (21±1°C)	T1	23.14h	24.51j
	T2	35.64e	37.67ef
	T3	49.31c	52.10c
	T4	53.99b	55.81b
	T5	63.54a	63.88a
0°C	T1	19.51i	20.30k
	T2	28.37g	31.52h
	T3	34.26ef	35.55fg
	T4	44.27d	45.48d
	T5	48.45c	50.46c
5°C	T1	15.61j	15.79l
	T2	20.81i	22.34jk
	T3	26.93g	27.39i
	T4	32.29f	34.28g
	T5	36.44e	38.69e

T1= Distilled water (control), T2= 0.5ml/l Florissant 100 + 200mg/l 8-hydroxyquinoline citrate, T3= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate, T4= 2% sucrose + 200mg/l 8-hydroxyquinoline citrate + 150mg/L citric acid, T5= 2% sucrose + 200mg/l 8-Hydroxyquinoline citrate + 150mg/l citric acid + 150mg/l 6-benzyladenine + 0.5ml/l Tween 20

The effect of interaction between storage temperature and holding solutions treatments on total carbohydrates (%) of *Limonium sinuatum* cv. Velvet Wings was presented in Table (22). The data showed that the highest values of total carbohydrates percentage in petals of *Limonium* cut flowers was recorded with flowers which were stored under room temperature (21±1°C) and treated with T5 holding solution.

DISCUSSION

Sucrose in holding solutions acts as carbohydrates stored in the stems and leaves and contributes in pigment synthesis, respiration and releasing energy needed for bud and flower opening. Sucrose in the holding solution increases the mechanical rigidity of the stem by inducing cell wall thickening and lignification of vascular tissues [35]. Sucrose extends the vase life by inhibiting ethylene production as mentioned by Han [36] on oriental liliy cv. Stargazer. Pun *et al*. [37] found that 5% sucrose recorded the best vase life and delayed the climacteric ethylene in petals. Mortazavi *et al.* [38] indicated that 100 mg/l sucrose increased relative water content in cut flower of rose cv. Varlon. Jones [39] found that the total soluble sugar content in *Leucadendron* cv. Slivan Red leaf tissue declined during 42 days of dry storage at 1°C. This decline was significantly inhibited by 20% pre-storage sucrose treatment. Sucrose addition to the vase solution exerts an effect on flower opening and senescence by increasing the hormones of cytokinin, auxin, gibberellins, abscisic acid and salicylic acid in several floral tissues, while decreases abscisic acid in outer tepals [40]. Germicides such as salts of 8-hydroxyquinoline as well as wetting agent like twen20 eliminate xylem vascular plugging in the flowering stems by the bacteria which reduced water uptake. The bacteria grow on proteins, amino acids, sugars and minerals released after cutting the surface of the flower stem into the vase water. 8-hydroxyquinoline and twen20 reduce water relation problems of cut stems by bypassing bacterially induced blockages of the xylem vessels or by dissolving air embolisms. 8-hydroxyquinoline citrate (8-HQC) increases the vase life by enhancing water uptake, diminishing transpirational loss and maintaining high water potential and turgidity of flowers, resulting in reducing fresh weight loss of flower stalk [41, 42]. Citric acid lowers water pH and inhibits the bacterial growth and therefore enhances water movement in the stem and consequently augment water uptake and petal water content. 8-HQC plus citric acid reduce transpiration loss of water and physiological loss in weight as revealed by Reddy *et al*. [43] on bird of paradise. Pietro *et al.* [44] indicated that the treatment with 8-hydroxyquinoline citrate and citric acid reduced carbohydrates and anthocyanin in cut red roses cv. Vega.

Cut flowers produce ethylene as they age. Preservative solutions contain anti-ethylene like Florissant 100 to reduce the leaf yellowing and senescence, as well as abscission of leaves, buds, petals and even the flowers and death caused by ethylene. Florissant 100 inhibits the effect of internal ethylene production by the flower and protects the flower against external ethylene coming from secondary sources. Consequently premature shrinking, petal drop and incomplete flowering are avoided and vase life is prolonged. Once treated, the flower will no longer respond negatively to ethylene. Benzyl adenine (BA) stimulates cell division, decrease respiration in plants and prevent leaf yellowing or browning in cut flowers. BA affects the total carbohydrates content due to that it enhances the availability of sugars in cells by increasing α-amylase and invertase activities [45]. BA increases leaves chlorophyll content and delays chlorophyll degradation [46, 47]. It reduces weight loss, chlorophyll and anthocyanin degradation and delays ethylene production and increases water uptake [48].

There is a positive correlation between respiration rate of cut flowers, an aging factor and the storing temperature. Cool storage reduces senescence, water loss and ethylene sensitivity of cut flowers. Khenizy [34] on gladiolus, found that sucrose, 8-HQS and citric acid combined improved anthocyanin content under ambient condition compared to those were in cold storage.

CONCLUSION

It is recommended to hold the cut flowering stems of *Limonium sinuatum* cv. Velvet Wings in a solution containing 2% sucrose + 200mg/l 8-hydroxyquinoline citrate + 150mg/l citric acid + 150 mg/l 6-benzyladenine + 0.5ml/l Tween20 under room temperature (21±1°C) for prolonging their longevity and improving quality of flowers.

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