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Post-harvest life of cut carnation (*Dianthus caryophyllus* L. cv. Malaga) as influenced by holding solutions

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Abstract
Carnation is preferred to rose and chrysanthemum in several exporting countries due to its excellent keeping quality, wide range of forms, ability to withstand distant transportation and remarkable ability to rehydrate after continuous shipping. The longevity of cut carnation flowers is one of the major aspects in floriculture industry and is the main characteristic determining the commercial value of the ornamental flowers. The cut flowers are deprived of water and nutrients after being detached from the mother plant. Hence, addition of chemical preservatives to the cut flowers is recommended to continue its physiological processes so that the longevity of the flowers can be extended. The vase life of cut carnation flowers is mainly associated with ethylene which initiates senescence and microorganisms which is responsible for vascular blockage. The study was conducted on the effect on post harvest life of cut carnation cultivar Malaga as influenced by different holding solutions. Cut carnations are treated with holding solution of silver thiosulphate, aluminium sulphate, benzyl adenine, gibberellic acid and combinations of the treatments to improve their vase life. Sucrose of 2 percent was added to all the treatments except control. The experiment results revealed that the holding solution of Sucrose 2 percent + *Aluminium sulphate* @ 300 ppm recorded the highest water uptake (5.39 g), water balance (8.79 g), fresh weight change (172.93 percent), earlier bud opening (6.33 days), flower diameter (5.27 cm), flower freshness (18.33 days), colour fading (18.33 days), longest vase life (21.33 days), total sugars (1.162 mg/g), reducing sugars (0.584 mg/g), anthocyanin (2.96 mg/g) and carotenoid content (0.147 mg/g). The transpirational loss of water (6.60g), physiological loss in weight (33.40 percent) and peroxidase activity (0.025 percent) was low for the treatment with holding solution of Sucrose 2% + $Al_2(SO_4)_3$ 300 ppm.

Keywords: Carnation, *Aluminium sulphate*, sucrose, vase life

Introduction
Carnation (*Dianthus caryophyllus* L.) is the most important cut flower in the world and occupies a place of great importance on account of its qualities: Excellent vase life, wide range of flower colours and forms, ability to withstand long distance transportation, rehydrate easily, lighter weight. The demand of cut flowers is increasing day by day in the market. Carnation is a climacteric flower that is highly sensitive to ethylene. Due to high perishability, cut flowers are vulnerable to large post-harvest losses upto 50 percent of the farm value. Carnations are more susceptible to mechanical and physical damages and microbial infections by diseases and pests during and after harvest. Floral preservatives affect the quality of cut flowers by extending the vase life, increasing flower size and maintaining the colour of leaves and petals. STS protects the cut flowers from senescence caused by ethylene. The use of STS in extending the vase life has been discouraged because STS contains silver, which is seen as a potential environmental pollutant. Sugars play an important role in the keeping quality of cut flowers because the amount of sugar contained in cut flowers is limited. The carbohydrate status of the petals has been proved to be one of the factors, which ultimately determine their longevity. Effects of sugar on the extension of the vase life of cut flowers are considered to be associated with the improvement of the water balance. A combination of sucrose four percent and $Al_2(SO_4)_3$ 300 ppm was found to be most effective in extending the vase life of gladiolus spikes upto 10.53 days (Anju *et al*., 2003) [1]. The flower stalks of rose cv. Red Sandra held in a vase solultion of BA 25 ppm + sucrose four percent had higher longevity of 15 days over the control of eight days (Lee and Kim, 1994) [11]. Gibberellic acid has been reported to increase the water uptake, maintain the water balance and increase the fresh weight, finally extending the vase life of cut flowers (Bhaskar and Rao, 1998) [2].

The present study was designed to assess the response of different holding solutions in enhancing the post-harvest life of carnation.

Materials and Methods

The study was undertaken in the Department of Floriculture and Landscaping, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore. The experiment was laid out in completely randomized block design consisting of eight treatments of different combinations details were as follows: H_1- STS @ 0.2 mM, H_2 -$A1_2(SO_4)_3$ @ 300 ppm, H_3 – BA @ 25 ppm, H_4 GA_3 @ 25 ppm, H_5-$A1_2(SO_4)_3$ @ 300ppm + STS @ 0.2mM H_6-$A1_2(SO_4)_3$ @ 300 ppm + BA @ 25 ppm, H_7 $A1_2(SO_4)_3$ @ 300 ppm GA_3@ 25ppm, H_8 Control (water). Sucrose @ 2% is added to all the treatments except control. For vase life studies, uniform and straight normal cut flowers at paint brush stage were harvested during morning hours. Immediately after harvest, the flower stalks were placed in a bucket of water. The leaves from lower one- third portion of the stalk were removed. Thereafter, 5-10 cm of the basal portion was cut under deionized water, packed, then placed in water and brought to the laboratory. The flowers were continuously held in the treatment solution and the vase life was expressed in days from the time of immersion in the test solution to the loss of ornamental value. The vase life of cut flower was evaluated daily by counting the number of days taken for the symptom of shrivelling and wilting. The intensity of anthocyanin pigment was determined by the method described by Kliewer (1970) [9]. The number of days taken for full opening of the flower from paint brush stage was recorded daily and expressed in days. The data recorded from the experiment were analyzed using a completely randomized design, replicated three times with five flowers per replication. The weight of each container and solution with and without cut flower was recorded every alternate day. While recording weights, everyday re-cutting of the floral stalk (about 1 cm) was done uniformly. The water uptake and fresh weight change were determined by the procedure according to Venkatarayappa *et al.* (1980) [15].

Results and Discussion

In the present investigations, sugar (sucrose), germicides (STS), growth regulators gibberellic acid (GA_3), benzyl adenine (BA) and aluminium sulphate $Al_2(SO_4)_3$ were considered as holding solution and their combination were studied. The results of the experiments revealed that the water uptake was highest in the holding solution containing Sucrose 2% + $Al_2(SO_4)_3$ @ 300 ppm which was superior over other treatments. The post-harvest treatments revealed that the senescence starts from day 12 onwards. In the present study, the maximum water uptake (5.39 g/stalk) was recorded with sucrose 2% + $Al_2(SO_4)_3$ @ 300 ppm in control on day 12. The increased water uptake might be due to translocated sucrose accumulated in flowers that increased the osmotic potential and improved the ability of the stalk to absorb water. Sucrose 3 percent with $Al_2(SO_4)_3$ @ 300 ppm in the holding solution increased the water uptake Rakesh *et al.* (2004) [13] in chrysanthemum. Sucrose @ 2 and 4 percent had significant effect on the water uptake, fresh weight bud opening and vase life. The transpirational loss of water (TLW) recorded was lowest (6.60 g/stalk) in the treatment Sucrose 2%+ $Al_2(SO_4)_3$ @ 300 ppm on day 12. TLW was significantly higher on day 3 than all other days. This may be due to the fact that aluminium compounds in vase water inhibit the microbial growth were found to reduce the rate of transpiration in cut flowers due to induced closure of stomata. Also when the rate of transpirational loss is more than the water uptake, then the cut carnations might have experienced water stress in tuberose (Bhaskar and Rao, 1998) [2]. Water deficit has a direct effect on turgor of cut flowers and would accelerate senescence (Halevy *et al.* 1978) [6]. The fresh weight of the flower stalk indicates that water and carbohydrate levels are essential in maintaining the flower quality in carnation. On day 12, the highest water balance (8.79 g/stalk) was recorded in the treatment with sucrose 2% + $Al_2(SO_4)_3$ 300 ppm. The increased water uptake and maintenance of normal levels of transpirational loss of water improved the positive water balance and thereby contributed to the increased fresh weight for longer period which ultimately prolonged the vase life. The rate of transpiration declines but tends to be higher than water uptake in the later stage of the vase life and results in negative water balance. A decrease in water potential and stomatal closure subsequently results in loss of turgor pressure that aluminium was effective in reducing the transpiration and increasing the longevity in carnation and rose.

An increase in the fresh weight can be achieved by maintaining a proper water flow to the stem and this is possible by using a wide range of preservative chemicals in the vase solution. The fresh weight of the flower stalk indicates that water and carbohydrate levels are essential in maintaining the flower quality in carnation. $Al_2(SO_4)_3$ is highly effective for higher bud opening and fresh weight retention with enhanced water uptake consequently extending the vase life. Sucrose 2% + $Al_2(SO_4)_3$ 300 ppm registered early bud opening within 6.33 days and late bud opening 8.33 days in control. Similarly, the same treatment recorded the highest flower diameter (5.27 cm) and lowest flower diameter (2.53 cm) in GA_3 @ 25 ppm. The early bud opening might be due to higher water uptake and similar results were obtained with sucrose 3% + $Al_2(SO_4)_3$ 300 ppm. Aluminium was found as the best combination with sucrose for normal bud opening. Aluminium overcomes the water stress thereby encouraging continuous water transport as supported by Murali (1990) [12]. Also there was decrease in flower diameter indicates the start of senescence from day 10 onwards. Thus, the combination of sucrose and $Al_2(SO_4)_3$ increased the flower diameter Kavitha *et al.*, (2004) [8]. The flower freshness and colour fading was also in harmony with the vase life. Thus, the treatment Sucrose 2% + $Al_2(SO_4)_3$ 300 ppm recorded longest freshness for 18.33 and registered shortest freshness for 11.67 days in control. Similar results were postulated by Bhattacharjee (1998) [3] in rose where $Al_2(SO_4)_3$ aids in greater water uptake and thereby maintained the freshness and colour of flowers for longer period.

Highest vase life (21.33 days) was recorded in the treatment with Sucrose 2% + $Al_2(SO_4)_3$ 300 ppm whereas in control which recorded a vase life of 14.67 days only. The combination of sucrose and $Al_2(SO_4)_3$ in holding solution improved the vase life. The holding solution contains at least two components that sugars provide a respiratory substrate and apparently the improvement may be due to inhibition of bacterial growth of water conducting tissues. This is in agreement with the findings of Kavitha *et al.* (2004) [8]. Physiological loss in weight (33.40%) was lowest in the

treatment with Sucrose 2% + $Al_2(SO_4)_3$ @ 300 ppm when compared with the treatment of Benzyl adenine @ 25 ppm with physiological loss in weight (65.93%). In general, the loss in weight was rapid with advancement of time are in corroboration with the findings of Divya (2003) [5] in rose stated that the combination of sucrose at 1.5% + $Al_2(SO_4)_3$ 300 ppm recorded less physiological loss in weight than the other treatments. In the present investigation, the flowers under the treatment with Sucrose 2% + $Al_2(SO_4)_3$ 300 ppm recorded minimum loss of integrity of the membrane (57.53 percent) and in control showed maximum loss of integrity of the membrane (98.55 percent) in the treatment of Benzyl adenine @ 25 ppm. The maintenance of membrane integrity led to better water relation in flower tissues thereby lowest leakage. Thus, the increased water uptake and low physiological loss in weight was achieved by the maintenance of cell integrity and positive water balance. The loss in integrity and an increase in permeability is a sign heralding senescence. Sucrose in the holding solution increased the vase life better than in control and this might be due to maintenance of mitochondrial structure in gerbera (Jona *et al*., 1989) [7].

In the treatment with Sucrose 2% + $Al_2(SO_4)_3$ 300 ppm, the highest total sugars (1.162 mg/g) and reducing sugars (0.584 mg/g) was recorded compared to low total sugars (0.275 mg/g) and reducing sugars (0.210 mg/g) in control on day 12. The carbohydrate depletion in the petals showed the initiation of senescence, since the amount of carbohydrate present in the flower bud at the moment of cutting is not sufficient to support respiration, maintenance and osmoregulation during vase life (Kuiper *et al*., 1995) [10] opined that there must be an import of carbohydrate into the flower bud, which was considered to be the sink, the sucrose treated flowers extended the post harvest life by delaying the senescence. In the present study, the treatment with Sucrose 2% + $Al_2(SO_4)_3$ 300 ppm recorded the lowest peroxidase activity (0.025 units/g of fresh weight) and highest peroxidase activity (0.045 units/g of fresh weight) in control. Thus, the peroxidase activity was registered to be highest indicating the initiation of stress towards the end of vase life. Discoloration or fading of colour is a common symptom of many senescing flowers. This shows the association of lowered peroxidase activity to the lowered metabolism and hence the postponement of senescence. Being one of the most widely studied enzymes, perioxidase was found associated with stress and destruction of cell membranes.

In this study, the treatment with Sucrose 2% + $Al_2(SO_4)_3$ 300 ppm recorded the highest anthocyanin content (2.96 mg/g) and lowest anthocyanin content (1.088 mg/g) in control. Hence, the retention of anthocyanin pigments in the flowers was due the presence of $Al_2(SO_4)_3$ in vase solution. Thus, $Al_2(SO_4)_3$ can be considered as a cheap and adequate substitute for costlier germicides like 8-HQC and $AgNO_3$ (Suneetha and Kumar, 1998) [14]. Carotenoid content (0.147 mg/g) was observed to be highest in the treatment Sucrose 2% + $Al_2(SO_4)_3$ 300 ppm and lowest carotenoid content (0.083 mg/g) on day 12. The highest carotenoid content might be due to addition of sucrose, which reduced the proteolytic breakdown and maintained the original colour. Hence, the retention of anthocyanin pigments in the flowers was due the presence of $Al_2(SO_4)_3$ in vase solution.

Table 1: Effect of holding solutions on the physical parameters in carnation cv. Malaga

Treatments	Water uptake (g)	Transpirational loss of water (g)	Water balance (g)	Fresh weight change (% of initial weight)	Bud opening (days)	Flower diameter (cm)	Flower freshness (days)	Colour fading (days)	Vase life (days)
H_1 - STS (0.2 Mm)	3.10	7.90	5.20	104.86	8.33	5.23	14.67	14.50	17.67
H_2 - $A1_2(SO_4)_3$ - (300 ppm)	5.39	6.60	8.79	172.93	6.33	5.27	18.33	18.33	21.33
H_3 - Benzyl adenine - BA (25 ppm)	1.28	7.53	3.75	80.07	8.33	4.67	12.67	12.67	15.00
H_4 - Gibberellic acid (GA3 @ 25 ppm)	1.55	7.00	4.55	76.04	8.33	2.53	13.33	13.50	16.67
H_5 - $A1_2(SO_4)_3$ - (300 ppm) + STS (0.2 mM)	4.34	6.73	7.61	131.71	7.00	4.97	16.50	17.00	19.33
H_6 - $A1_2(SO_4)_3$ - (300 ppm) + BA (25 ppm)	4.13	7.80	6.33	109.98	7.33	4.60	15.33	16.00	19.00
H_7 - $A1_2(SO_4)_3$ - (300 ppm) + GA_3 (25 ppm)	3.18	7.80	5.38	95.44	8.00	5.17	15.33	15.00	18.00
H_8 - Control(water)	2.17	7.08	5.08	75.84	8.33	3.87	11.67	10.67	14.67
SE(d)	0.150	0.227	0.762	3.069	0.674	0.139	0.464	0.559	0.624
CD (5%)	0.317	0.482	1.905	6.505	NS	0.296	0.984	1.185	1.322

Table 2: Effect of holding solutions on the physiological and biochemical parameters in carnation cv. Malaga

	Physiological parameters						
	Physiological loss in weight (%)	Loss of membrane integrity (%)	Total sugar content (mg/g)	Reducing sugar content (mg/g)	Peroxidase activity (units/g fresh weight)	Anthocyanin content (mg/g)	Carotenoid content (mg/g)
H_1 - STS (0.2 Mm)	57.33	91.86	0.774	0.393	0.038	1.317	0.115
H_2 - $A1_2(SO_4)_3$ - (300 ppm)	33.40	57.53	1.162	0.584	0.025	2.964	0.147
H_3 - Benzyl adenine - BA (25 ppm)	65.93	98.55	0.766	0.392	0.032	2.088	0.114
H_4 - Gibberellic acid (GA3 @ 25 ppm)	64.33	95.98	0.636	0.320	0.034	2.027	0.107
H_5 - $A1_2(SO_4)_3$ - (300 ppm) + STS (0.2 mM)	47.70	77.82	1.073	0.540	0.026	2.660	0.134
H_6 - $A1_2(SO_4)_3$ - (300 ppm) + BA (25 ppm)	58.11	86.77	0.985	0.493	0.035	2.534	0.124
H_7 - $A1_2(SO_4)_3$ - (300 ppm) + GA_3 (25 ppm)	57.22	88.97	0.876	0.438	0.032	2.413	0.122
H_8 - Control(water)	61.00	94.60	0.275	0.210	0.045	1.088	0.083
SE(d)	2.407	0.747	0.0015	0.0015	0.0005	0.0017	0.0014
CD (5%)	5.103	1.583	0.0032	0.0032	0.0010	0.0037	0.0030

Conclusion

The holding solution of Sucrose 2% + $Al_2(SO_4)_3$ 300 ppm recorded the highest water uptake, fresh weight change, earlier bud opening (6.33 days), longest vase life (21.33 days), anthocyanin (2.964 mg/g) and lowest physiological loss in weight (33.40 percent).

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