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PULSING PRESERVATIVES TO PROLONG VASE LIFE OF CUT ROSE FLOWERS IN BAHIR DAR, NORTHWESTERN ETHIOPIA

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ABSTRACT

The longevity of cut flowers including cut roses can be however prolonged using different pulsing preservatives where researches in this regard are lacking in the country. Keeping these bottlenecks of the sector in mind, this study was therefore initiated with objective to evaluate the effectiveness of different pulsing preservatives in prolonging vase life of cut rose varieties. The experiment was conducted at Tana Flora PLC in Bahir Dar, Ethiopia. As pulsing preservatives $Al_2(SO_4)_3$(250 mg-1), $Ca(ClO)_2$ (66.7 mg-1), STS [$Ag(S_2O_3)_2$] (0.5 ml-1), Sugar (20 g-1) and distilled water were used. The three rose varieties namely: Upper class, Athena and Moon walk were used. Healthy flower buds having uniform length and harvested early in the morning were put immediately in containers filled with the respective concentration of pulsing preservatives. Flasks with six rose flowers each were placed in pre-cooling room (8-10 OC) for about 2 hours. Finally, treated cuttings were transferred into experimental room with temperature of 22-250C and 75% relative humidity and arranged in Complete Randomized Design (CRD) with three replications. At this time, pulsing preservatives were replaced by distilled water. The analysis of variance revealed that most of parameters were highly significantly influenced by the main as well as interaction effects of pulsing preservative and varieties ($P<0.0$). Maximum water uptake (7.73 g/flower/day), transpiration loss (7.08 g/flower/day), flower fresh weight (21.77 g/flowers), flower head diameter (7.6 cm), and maximum flower vase life (23 days) were recorded in Athena variety pulsed with STS.

Contribution/Originality: This study is one of very few studies which have investigated to improve the shelf life and quality of rose flowers particularly in our country. Therefore, the present finding will contribute to flower growers through identifying appropriate pulsing preservatives for rose cut flower.

1. INTRODUCTION

Rose (Rosa hybrid L.) belongs to the family Rosaceae, under which more than 150 species and 1400 cultivars are consisted. Rose is one of the most popular cut flowers since the dawn of civilization (Elgimabi, 2011). Rose enjoys superiority over all other flowers being extensively used for decorative purposes and is prized for its delicate nature, beauty, charm and aroma. Rose plants produce an exquisite floral display consisting of many vibrant colors, shapes, sizes and perfumes. Throughout the history of civilization, no other flower has been so immortalized and integrated into daily life of the people as the rose. Thus, it is rightly called as the queen of flowers (Gault and Synge, 1971; Elgimabi, 2011).

The flower sector in Ethiopia is flourishing from year to year. The number exporting farms as well as assortment of flowers exported are in increasing trend. the share of Ethiopian flowers in European exports doubled from 6% in 2005 to 12% in 2010. Accordingly, Ethiopia is becoming one of the top five flower suppliers to European markets including Kenya, Ecuador, Columbia and Israel and holds an impressive second place among Dutch auction suppliers.

Roses accounted more than 80% of the cut flower production both in value and area coverage in Ethiopia. Many varieties of the so called Hybrid Tea, Intermediate and Sweetheart roses are currently produced in modern greenhouses which are mostly concentrated around Addis Ababa, the capital city of Ethiopia . Recently however, floricultural enterprises are also established and developed in other parts of the country like Bahir Dar and Hawassa.

Since flowers including roses are produced mostly for export market, the commercial growers are facing among others the problem associated with shorter shelf life of cut roses distended for export market. About 20% of fresh flowers lose their quality while passing through the market channels (harvesting, packaging, transportation, and sale) and a large deal of remaining flowers is sold at low quality conditions that dissatisfy the consumer which are mostly associated to physiological and pathological problems during postharvest handling.

Under normal conditions, cut flowers last only for a few days in maintaining their beauty and attractiveness. On the other hand, people like to enjoy the natural beauty and appearance of cut flowers as long as possible (Tsegaw *et al.*, 2011; Zamani *et al.*, 2011). Cut flowers are literally cut off from their source of life. However, as living organisms the respiration and transpiration occurred in cut result loss of water and breakdown of nutrients which accelerate the aging process and reduction of postharvest or vase life and lead senescence. the main reason for senescence of cut flowers is wilting which is associated with the reduction of water supply caused by bending of floral axis just below the flower heads. The reduction of water transport through cut flowers is also attributed by physiological occultation of the plant itself, air embolism or microorganisms which plug xylem vessels of flower stems (Elgimabi, 2011).

Extensions of vase life of cut flowers through the use of substance as a source of energy as well as chemicals that prevent the development of micro-organisms have been recorded by various researches. Addition of preservatives in the vase solutions also delayed senescence and extend the vase life of cut flowers through prevention of ethylene synthesis and pathogen development which shorten the vase life of flowers including roses (Nigussie, 2005; Elgimabi, 2011). according to them, aluminum sulfate (Al2(SO4)3) as antimicrobial compound to prevent development of microbial organisms in vase solution to prolong vase life of several cut flowers. The compound also acidifies vase solution, diminishes bacterial proliferation and enhances water uptake (Tsegaw *et al.*, 2011) which can be used alone or in combination of sucrose.

Similarly, 8-hydroxyquinoline sulfate (8-HQS) is also the other important chemicals used in flower industry to reduce the occurrence of decaying microorganisms in vase solutions of cut flowers. Silver thiosulfate (STS) is also known to suppress autocatalytic ethylene production by inhibition of ethylene action. Although increasing importance of floricultural industry for Ethiopian economy, researches on postharvest handling of fresh flowers is lacking in Ethiopia. Flower growers as well as exporters are tackling with limited knowledge related to postharvest technologies of cut flowers including rose flowers. Therefore, the present study was initiated with improvement of vase life of cut flowers through identifying appropriate pulsing preservatives for export oriented rose cut flower.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The study was conducted in vase life experimental room of Tana Flora PLC, Bahir Dar, Ethiopia from October 2016 to December 2016. The site is located at 11.710 N latitude and 37.30 ^{0} E longitude with 1850 meter above sea level. The location received annually on average about 1250 mm rainfall and has relative humidity of about 75%.

2.2. Experimental Materials, Design and Pulsing Procedures

Three varieties of rose *(Rosa hybrid* L.*)* namely, Upper class, Athena and Moon walk were used, which are mostly produced for export market. Five pulsing preservatives: aluminum sulfate ($Al_2(SO_4)_3$) (250 mg l^{-1}) , calcium hypochlorite ($Ca(ClO_2$ (66.7 mg l^{-1}), Silver thio-sulfate (STS) (0.5 ml $^{-1}$), sugar (20 g $^{-l}$) and distilled water as a control were used. The cut flowers were obtained from Tana Flora PLC, which is one of the biggest producers and exporters of cut roses in Amhara Region as well as in the country.

Matured rose buds were harvested early in the morning at standard commercial harvest maturity stage where flower buds were tight and the sepals were enclosed in the floral bud and attained desirable size. Harvested flower buds having uniform medium-sized thickness and 60 cm length were used for the study and immediately kept in flasks containing respective preservative solutions. The depths of each solution in the flasks were maintained in such a way that about 10 cm of the flower stems was covered with preservative solutions.

To simulate flower handling practices of exporters including Tana Flower PLC, rose cut flowers in buckets were kept in pre-cooling room (8-10°C) for two hours to remove field heat. After field heat removal, cut flowers were sorted, graded and bunched to fit the export standard. Sorted and export standard rose flowers were then kept in buckets filled with respective new pulsing preservative solutions and kept in final cooling room (2-4 °C) for 24 hours.

After 24 hours in cold room, flowers stems were transferred in to vase life testing room with temperature at the range of 22-25 ^{0}C and relative humidity of 75% and all preservative solutions were replaced with distilled water. Moreover, about 2 cm slant cut was made at the bottom end of the stems to improve water uptake of flowers. Finally, six flower stems were kept in experimental flask containing 1000 ml distilled and put on working table with complete randomized design (CRD) in three replications.

2.3. Data Collection and Analysis

Flower fresh weight (g): The flask was weighed with flask + solution + flowers. The weight of flask and solution was subtracted from the total weight which signifies fresh weight of flowers. This process was repeated everyday and weight per flower stem was computed.

Water uptake (g): For determining water uptake, flasks were weighed with solution without flower and the consecutive difference in weight signifies the water uptake by flowers and expressed in grams per flower.

Transpiration loss (g): Flowers were weighted at daily basis along with solution and flowers and the consecutive difference in weights represents the transpiration loss and expressed in grams per flower.

Water balance (g): Water balance was calculated by deducting the total transpiration loss from water uptake.

Wilting percentage (%): The number of wilted flowers in each treatment were counted and expressed in percentage to the total number of flowers in flask.

Flower head diameter (cm): The diameters of four randomly selected flowers at the time full bloom were measured using caliper and the average mean values computed and used for further analysis.

Vase life or flower longevity (days): Vase life of cut flowers was determined on the percentage of wilting. When the neck of 50% of the flowers in the flask bent over, the vase life was terminated. At this point discoloration and loss of petals were started. The number of days starting from harvesting until this stage was counted and used for evaluation.

Collected data were subjected to analysis of variance (ANOVA) using SAS- computer software version 9.1.3. Whenever the ANOVA results showed significant difference among treatments, mean separation was performed using least significant difference (LSD) at 1% or 5% significance level.

3. RESULTS AND DISCUSSION

3.1. Postharvest Physiology as Affected By Pulsing Preservative and Rose Variety

Water Uptake

Daily water uptake of cut rose flowers were highly significantly influenced by pulsing preservative and variety as well as their interaction. Silver thio-sulphate (STS) pulsed cut rose flowers absorbed on average the maximum water (5.78 g/flower/day) during the vase life period followed by calcium hypochlorite (4.3 g/flower/day) pulsed flowers (Figure 1A). Although in decreasing trend, STS pulsed cut flowers absorbed daily higher quantity of water compared to those treated other preservatives. Especially cut roses pulsed with distilled water lost their water uptake sharply starting from the 6th day of the vase life (Figure 2A).

Rose variety also affected the daily water uptake of cut flowers. Athena variety recorded on average maximum water uptake (5.09 g/flower) during the vase life followed by Moon walk (3.39 g/flower) and Upper class (1.83 g/flower) as indicated in Figure 1B. Similar trends were also observed in daily water uptake where Athena variety absorbed always greater amount of water than the other rose varieties (Figure 2B).

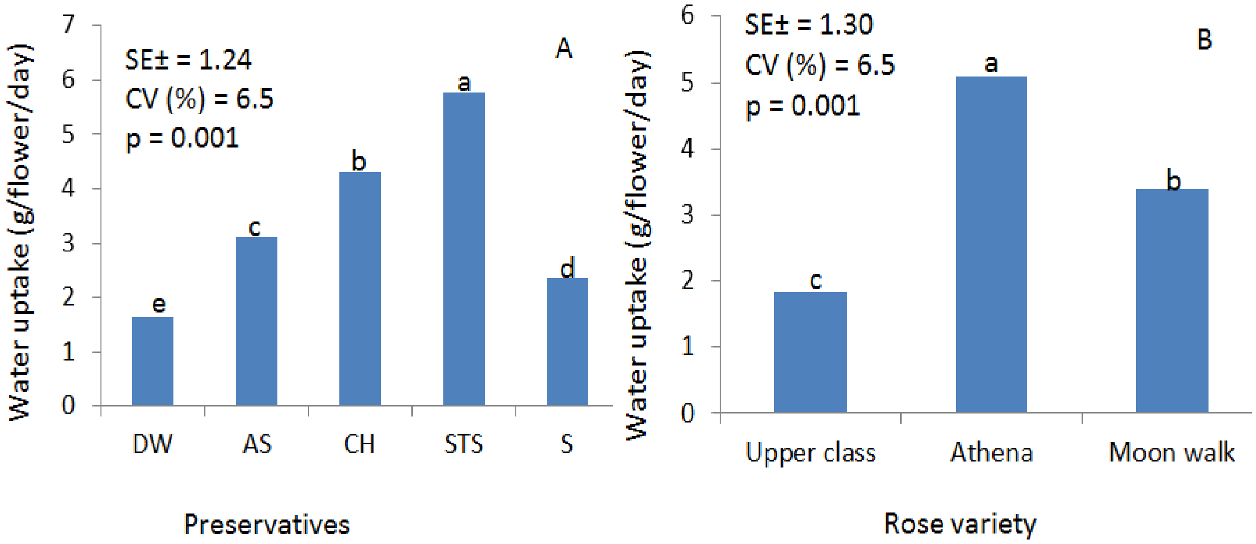

Figure-1. Mean water uptake of cut flowers during vase life as affected by preservative (A) and rose variety (B)

Source: modified from collected row data during the experiment

Means with the same letter(s) in each category are not significant; SE± = Standard error; CV= Coefficient of variation; P- probability value; DW = Distilled water; AS = Aluminum sulfate; CH = calcium hypochlorite; S = Sugar

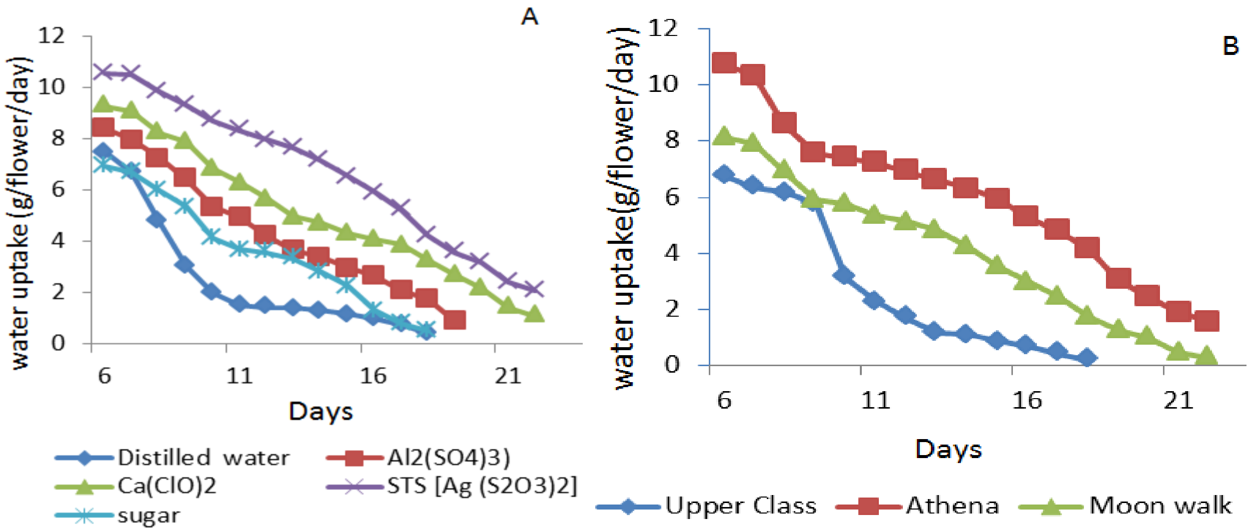

Figure-2. Daily water uptake of rose flowers during vase life as affected by pulsing preservative (A) and variety (B)
Source: modified from collected row data during the experiment

In the interaction effect, Athena variety pulsed with STS took up daily on average 7.73 g/flower water during the vase life followed by the treatment combinations of Athena x calcium hypochlorite (6.59 g/flower) and Moon walk x STS (5.7 g/flower) an indicated in Table 1.

Improving water uptake of cut flowers during the vase life have been reported by various researchers which is in line with the findings of the present study (Singh *et al.*, 2004; Marandi *et al.*, 2011; Moody *et al.*, 2014). The results can be associated with the biocide effects of both chemicals. Both chemicals have the ability to inhibit the growth of microbial organisms especially in vase solution which may block water transport in the vascular system of cut flowers as indicated by Marousky (1969). In agreement with these findings, effective transportation of water within the floral stems and reduced stem blockage were also observed by various researches in different cut flowers . The different repose of rose varieties to the pulsing preservatives indicated in the present study is may be associated with the genetic makeup of the varieties (Moody *et al.*, 2014) where the variety Athena could be more responsive to STS than the varieties Moon Walk and Upper Class do.

Water Loss through Transpiration

Preservative and rose variety in their main as well as interaction effects strongly influenced cut flower water loss through transpiration. Highest maximum transpiration loss of water during vase life was occurred on rose cut flowers which were pulsed with STS (5.66g/flower/day) followed with calcium hypochlorite (4.08 g/flower/day). Minimum rate of water transpiration loss was however recorded on cut flowers pulsed with aluminum sulfate (3.64 g/flower/day) sugar (2.8 g/flower/day) and distilled water (2.41 g/flower/day) in descendent order (Figure 3A). Similarly, cut rose variety highly significantly influenced daily average water loss through transpiration where the variety Athena lost the maximum water (5.22 g/flower/day) followed by Moon walk (3.82 g/flower/day) and Upper class (2.12 g/flower/day) varieties of rose flowers (Figure 3B).

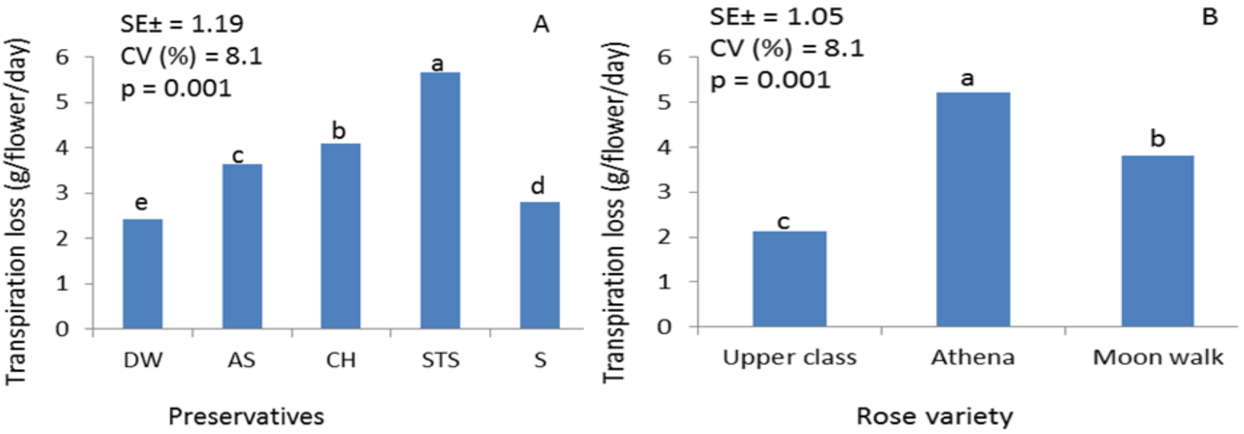

Figure-3. Mean water transpiration loss of rose flowers during vase life as affected by preservative (A) and variety (B)

Source: modified from collected row data during the experiment:

Means with the same letter(s) in each category are not significant; SE± = Standard error; CV= Coefficient of variation; P- probability level; DW = Distilled water; AS = Aluminum sulfate; CH = calcium hypochlorite; STS = Silver thio- sulfate; S = Sugar

Loss of water through transpiration increased progressively up to 20th day of vase life on rose flowers, which were pulsed with STS and calcium hypochlorite while water loss on distilled water, and sugar pulsed cut flowers decreased after 8th day of the vase life as indicated in Figure 4A. Rose flowers pulsed with sugar showed up and down progress of water transpiration loss. This is probably due to the fact that sugar act only as food but not as antimicrobial agent that may stimulate the growth and development of microorganisms. Flowers placed in water without antimicrobial compounds had a low water potential as a result of vascular blockage in the lower most segment of the stem. Thus, sugars with biocides are becoming important commercial preservatives for several cut flowers.

Similarly, water loss through transpiration increased progressively up to 18th day of the vase life of Athena variety while it sharply reduced after 16th day in Moon walk and after 10th day in upper class varieties (Figure 4B).

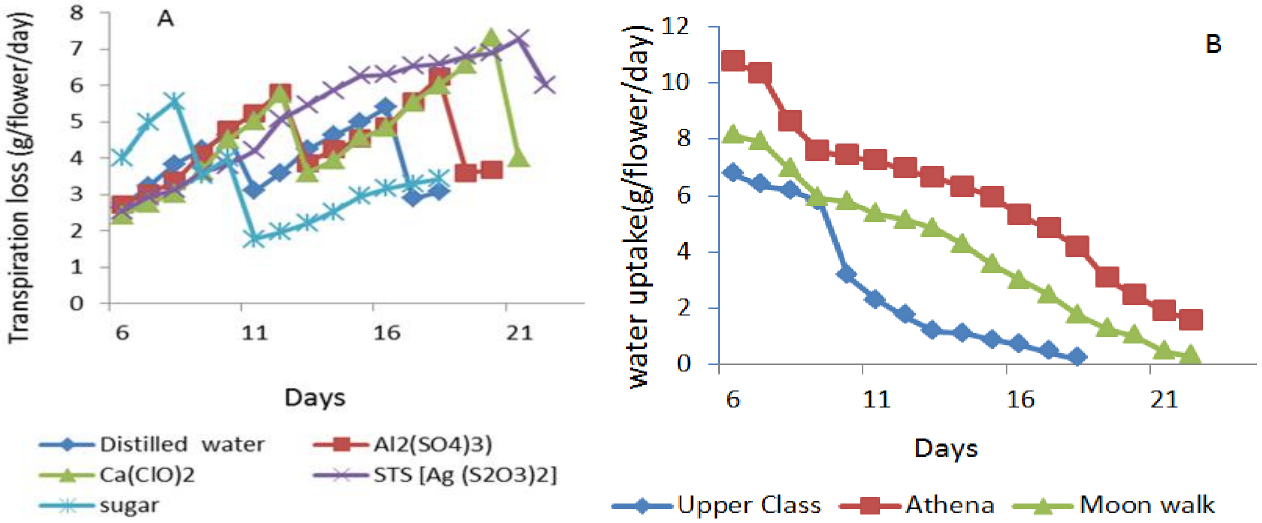

Figure-4. Daily water transpiration loss of cut flowers during vase life as affected by pulsing preservative (A) and rose variety (B)

Source: modified from collected row data during the experiment

Similarly, the interaction effect significant maximum water transpiration loss was observed on Athena (7.08 g/flower/day) and Moon walk (5.81 g/flower/day) varieties, which were pulsed with STS followed on Athena variety (5.51 g/flower/day) that was pulsed with calcium hypochlorite. Minimum daily water losses through transpiration were obtained on Moon walk variety pulsed with distilled water (1.11 g/flower/day) and on Upper class pulsed with sugar (1.15 g/flower/day) as indicated in Table 1.

Table-1. Mean water uptake and transpiration loss during the vase life of rose flower as affected by preservative and variety

Rose variety	Pulsing preservatives	Water uptake (g/flower/day)	Transpiration loss (g/flower/day)
Upper class	Distilled water	1.11i	1.50g
	Aluminum sulfate	1.53h	1.88hg
	Calcium hypochlorite	1.66h	1.92h
	Silver thio- sulfate	3.84e	4.08c
	Sugar	1.02i	1.15gi
Athena	Distilled water	3.06f	4.62e
	Aluminum sulfate	4.61d	4.90d
	Calcium hypochlorite	6.59b	5.51b
	Silver thio- sulfate	7.73a	7.08a
	Sugar	3.47f	4.01f
Moon walk	Distilled water	0.76j	1.11j
	Aluminum sulfate	3.23f	4.14f
	Calcium hypochlorite	4.65d	4.82d
	Silver thio- sulfate	5.70c	5.81c
	Sugar	2.63g	3.25g
SE±		1.30	1.05
CV (%)		6.5	8.1
P-value		0.001	0.001

Source: modified from collected row data during the experiment

Means with the same letter(s) in column are not significant; SE± = Standard error; CV = Coefficient of variation; P = probability values

Water stress occurs when the rate of transpiration exceeds the rate of water uptake by plants including in cut flowers which causes wilting and termination of vase life (Halevy, 1976). According to Burdett (1970) water loss from flowers including roses shapely decreased after cutting due to the closure of stomata which is mostly parallel to the water uptake. As water uptake increases, the water loss also increases before wilting of the cut flowers which is in line with the results of this study where water uptake as well as transpiration loss was increased on STS pulsed cut rose flowers. Higher water uptake may led to higher transpiration losses of water to avoid temporary stress which in turn led to an increase of cell membrane viscosity. The lowest water transpiration loss observed especially in distilled water pulsed flowers in this study is probably due to the reduced water uptake thereby the quantity of water retained in the floral tissue was meager that led to early wilting of cut flowers.

Water Balance

Water balance of STS pulsed cut rose flowers was positive until the 15th day of vase life while water balance of distilled water pulsed flowers showed negative water balance soon after the 8th day of the vase life. Similarly, cut rose flowers pulsed with sugar showed negative water balance after 10th day of the vase life (Figure 5A). Similarly, rose variety influenced the water balance of cut flowers during the vase life where the variety Athena had positive and higher water balance up to the 14th day of the vase life compared to other varieties. Upper class on the other hand had generally lower water balance, where its water balance was negative soon after the 9th day of the vase life (Figure 5B).

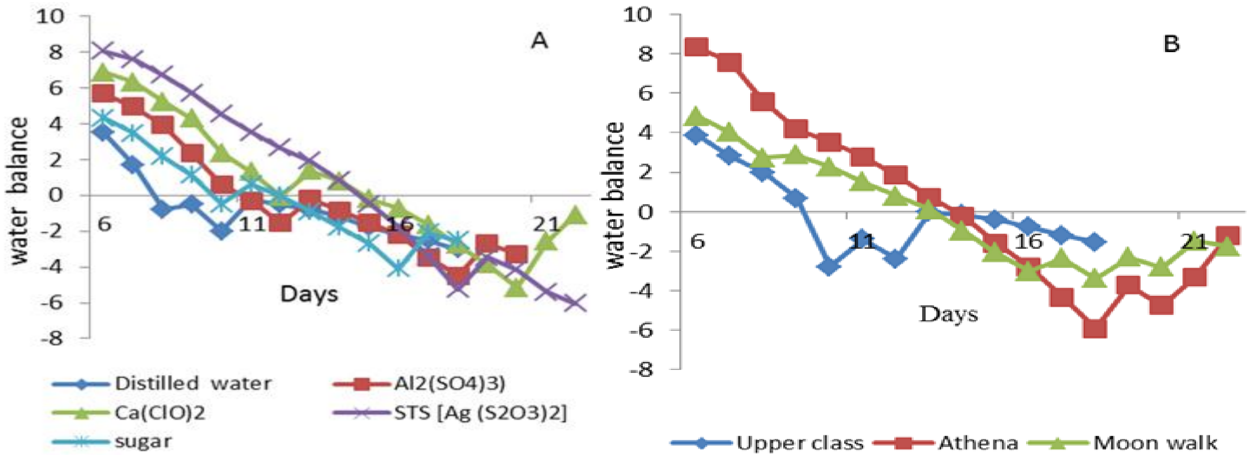

Figure-5. Daily water balance flowers during vase life as affected by pulsing preservative (A) and rose variety (B)

Source: modified from collected row data during the experiment

Water balance in a given cut flower is considered as determining factor for its quality and longevity/vase life which is influenced by the uptake and transpiration loss of water of the given flower (Da Silva, 2003). If water loss through transpiration exceeds the water uptake, wilting of the cut flowers will be occurred which terminates the vase life of cut flowers (He *et al.*, 2006). Higher water balance observed in STS and calcium hypochlorite pulsed rose flowers in the present study can be associated with the antimicrobial effects of the chemicals that kill microbes which block xylem vessel of cut flowers as indicated by various researchers (Nowak and Rudnicki, 1990; Singh *et al.*, 2004; Marandi *et al.*, 2011; Tsegaw *et al.*, 2011). Application of such chemical on vase solutions resulted longer vase life on cut flowers which is generally in line with findings of the present study and various scholars (He *et al.*, 2006).

Wilting Percentage

Wilting of flowers was influenced by the main as well as interaction effects of rose variety pulsing preservative. About 72% of STS pulsed sample flowers were wilted after 21 days while 75% of distilled water-pulsed flowers wilted soon after 9 days. On the other hand, about 76% of cut flowers pulsed with calcium hypochlorite and sugar were wilted after 19 and 13 days, respectively (Table 2). Pulsing of rose flowers with STS and calcium hypochlorite delayed the start of wilting by two days compared to other pulsing preservatives. Rose varieties used in this study had also different response to wilting. About 75% of cut flowers of Athena variety wilted after 21 days while 75% of the cut flowers of Upper class wilted after 11 days (Table 2).

Table-2. Wilting percentage of cut flowers during vase life as affected by pulsing preservative and rose variety

Preservative	**Wilting Percentage (%)**												
	Days												
	0	1	3	5	7	9	11	13	15	17	19	21	23
Distilled water	0	0	0	0	16	75	100	100	100	100	100	100	100
$Al_2(SO_4)_3$	0	0	0	0	8	16	41	41	57	87	87	100	100
$Ca(ClO)_2$	0	0	0	0	0	0	16	40	48	62	76	100	100
STS [Ag $(S_2O_3)_2$]	0	0	0	0	0	0	16	35	41	58	65	72	100
Sugar	0	0	0	0	10	42	55	76	100	100	100	100	100
Rose variety													
Upper class	0	0	0	0	20	56	75	100	100	100	100	100	100
Athena	0	0	0	0	0	5	5	5	10	34	62	74	100
Moon walk	0	0	0	0	5	25	33	47	66	100	100	100	100

Source: modified from collected row data during the experiment

In the interaction effect, Athena variety pulsed with STS wilted after 23 days while Moon walk and Upper class varieties wilted after 19 and 17 days, respectively. On the other hand, Upper class, Moon Walk and Athena varieties of roses pulsed with distilled water wilted after 9, 11 and 17 days, respectively (Table 3). The results of the present study clearly indicated that pulsing cut flowers with STS as well as calcium hypochlorite reduced wilting percentage and thus prolonged the shelf life of all rose varieties used in the present study. Such prolonged vase life of rose flowers is due to antimicrobial effects of STS as well as calcium hypochlorite, which kill microorganisms that block xylem vessels of cut flowers. The microbial effects of these chemicals are also reported by various researchers (He *et al.*, 2006).

Table-3. Wilting percentage of rose flowers as affected by interaction effect of pulsing preservative and variety

Rose variety	**Pulsing preservative**	**Wilting Percentage (%)**												
		Days												
		0	1	3	5	7	9	11	13	15	17	19	21	23
Upper class	Distilled water	0	0	0	0	50	75	100	100	100	100	100	100	100
	Aluminum sulfate	0	0	0	0	0	50	75	100	100	100	100	100	100
	Calcium hypochlorite	0	0	0	0	0	25	50	50	75	100	100	100	100
	Silver thio-sulfate	0	0	0	0	0	0	0	25	50	75	100	100	100
	Sugar	0	0	0	0	25	50	100	0	100	100	100	100	100
Athena	Distilled water	0	0	0	0	0	0	50	75	100	100	100	100	100
	Aluminum sulfate	0	0	0	0	0	0	0	0	25	50	75	100	100
	Calcium hypochlorite	0	0	0	0	0	0	0	0	0	25	50	75	100
	Silver thio-sulfate	0	0	0	0	0	0	0	0	0	0	0	25	75
	Sugar	0	0	0	0	0	0	0	25	50	100	100	100	100
Moon walk	Distilled water	0	0	0	0	50	75	100	100	100	100	100	100	100
	Aluminum sulfate	0	0	0	0	0	0	25	50	75	100	100	100	100
	Calcium hypochlorite	0	0	0	0	0	0	0	25	50	75	100	100	100
	Silver thio-sulfate	0	0	0	0	0	0	0	0	25	50	75	100	100
	Sugar	0	0	0	0	25	50	100	100	100	100	100	100	100

Source: modified from collected row data during the experiment

Vase Life of Cut Flowers

Vase life or flower longevity was terminated as the neck of 75% of cut flowers was bent over. Accordingly, pulsing preservative and rose variety as well as their interaction influenced vase life of cut flowers. Among the tested preservatives, STS significantly maintained the vase life of cut flowers longer (22.3 days) than other preservatives. While pulsing of cut flowers with calcium hypochlorite maintained the vase life of cut flower for 19 days, distilled water could retain the longevity only for 13 days (Figure 6A). While Athena variety was maintained for about 21.4 days, the vase life of Moon walk and Upper class were lasted within 17.8 and 13.4 days, respectively (Figure 6B).

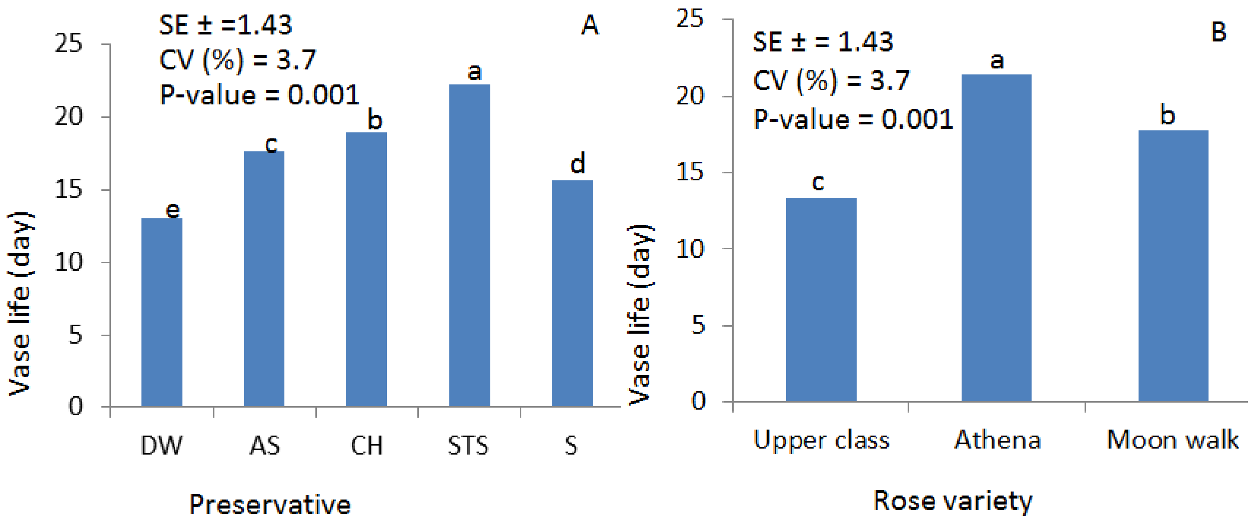

Figure-6. Mean vase life of rose flowers as affected by preservative (A) and variety (B)

Source: modified from collected row data during the experiment

Means with the same letters in are not significant; SE± = Standard error; CV= Coefficient of variation; P-probability value; DW = Distilled water; AS = Aluminum sulfate; CH = calcium hypochlorite; STS = Silver thio-sulfate; S = Sugar

Similarly, the interaction effect of pulsing preservative and rose variety strongly influenced the vase life. Significant maximum vase life (23 days) was observed on Athena variety pulsed with STS and calcium hypochlorite. Minimum vase life was observed on Moon walk variety pulsed with distilled water (9 days) as indicated in Table 4.

Pre-treating of rose cut flowers with STS and calcium hypochlorite generally increased the vase life in the present study. The fact that both preservatives have antibiotic effect against microorganisms that damage as well as block the xylem vessel of cut flower, they also obviously improve the vase life of cut flowers which is in line with the findings of Serek and Trolle (2000). Ethylene is responsible for senescence and termination of vase life of cut flowers. Prolonged vase life of STS-pulsed rose flowers in the present study is probably associated with reduced ethylene production in pulsed cut flowers, which is in agreement with the findings of other researchers (Serek *et al.*, 1995; Serek and Trolle, 2000; Hunter *et al.*, 2004; Reid, 2004).

Table-4. Vase life of rose flowers as affected by interaction of pulsing preservative and variety

Rose variety	**Preservatives**				
	Distilled water	**Aluminum sulfate**	**Calcium hypochlorite**	**Silver thio- sulfate**	**Sugar**
Upper class	11g	13f	13f	19c	11g
Athena	19c	21b	23ab	23a	19c
Moon walk	9h	19c	21bc	21b	17e
SE±		1.43			
CV (%)		3.7			
P-value		0.001			

Source: modified from collected row data during the experiment

Means with the same letter(s) are not significant; SE± = Standard error; CV= Coefficient of variation; P-probability level

3.2. Effects of Pulsing Preservative and Rose Variety on Growth and Development of Cut Flowers

Flower Head Diameter

Pulsing preservative and rose variety influenced flower head diameter of full bloomed cut flowers in the main as well as their interaction effects. The maximum flower head diameter was observed on STS-pulsed cut flowers (7.1cm) followed on calcium hypochlorite (6.11cm) and aluminum sulfate (5.8m) pulsed cut flowers while the minimum was observed on distilled water pulsed cut flowers. On the other hand, flower head diameters of 6.74, 5.5 and 4.7 cm were observed on Athena, Moon walk and Upper class cut flowers, respectively (Table 5). In the interaction effect, maximum flower head diameters at full bloom of cut flowers were observed when Athena variety was pulsed with STS (7.6 cm) and calcium hypochlorite (7.26 cm). Minimum flower head diameters were observed on Upper class variety pulsed with distilled water (Table 6).

Rose flowers are generally harvested as matured bud stage. The growth of buds is thus an important quality parameter which can be influenced among other with pulsing preservatives. In this regard, an increased flower diameter when 200 mg of HQS l-1 was used in the pulsing solution, which of course varied among the varieties tested. High antibacterial effect of the chemical can hinder the accumulation of bacteria at the end of stem as well as in the solution, which leads to vessels plugging. Moreover, the reduced ethylene synthesis due to STS pulsing (Zagory and Reid, 1986) may improve growth and development of flower buds by increasing water uptake and transpiration and thus prolonging vase life as indicated in the present study.

Flower Fresh Weight

Fresh weight of rose flowers at the end of the vase life was also influenced by pulsing preservative and variety as well as their interaction effects. STS-pulsed cut flowers had the highest fresh weight followed by calcium hypochlorite pulsed cut flowers. Similarly, Athena variety recorded the maximum fresh weight followed by Moon walk variety with the values of 18.83 and 17.4 g/flower, respectively (Table 5).

Moreover, Athena and Moonwalk varieties which were pulsed with STS recorded the maximum cut flower fresh weights of 21.77 g/flower and 21.76 g/flower, respectively. Minimum average fresh weights were recorded from Moon walk and Upper class varieties, which were pulsed with distilled water (Table 6). Similar trends were observed in daily flower fresh weight development of each variety during the vase life. Fresh weights of Athena and Moon walk rose varieties pulsed with STS were generally higher than other combination of preservative and variety.

Table-5. Effects of preservative and rose variety on flower head diameter and fresh weight of cut flower

Pulsing preservative	Head diameter (cm)	Fresh weight (g)
Distilled water	4.2e	12.34e
Aluminum sulfate	5.8c	16.19c
Calcium hypochlorite	6.11b	18.83b
Silver thio- sulfate	7.1a	20.35a
Sugar	5.02d	14.24d
SE±	0.56	1.20
CV (%)	0.28	4.3
P-value	<0.001	<0.001
Rose variety		
Upper Class	4.7c	12.43c
Athena	6.74a	19.34a
Moon walk	5.54b	17.4b
SE±	0.56	1.2
CV (%)	0.28	4.3
P-value	<0.001	<0.001

Source: modified from collected row data during the experiment

Means with the same letter(s) in column are not significant; SE± = Standard error; CV= Coefficient of variation; P- probability level

Table-6. Some growth parameters of cut flowers as affected by interaction effect of pulsing preventive and rose variety

Rose variety	Preservative	Head diameter (cm)	Fresh weight (g/flower)
Upper class	Distilled water	3.2e	10.21f
	Aluminum sulfate	5.7c	12.22e
	Calcium hypochlorite	6.01bc	12.46e
	Silver thio- sulfate	6.3b	17.54c
	Sugar	4.71c	9.72f
Athena	Distilled water	5.95cd	17.76c
	Aluminum sulfate	6.69b	18.23b
	Calcium hypochlorite	7.2abc	21.17a
	Silver thio- sulfate	7.8a	21.77a
	Sugar	6.4b	17.25c
Moon walk	Distilled water	4.01d	9.05f
	Aluminum sulfate	5.1c	18. 1b
	Calcium hypochlorite	6.7b	20.86ab
	Silver thio- sulfate	7.63ab	21.76a
	Sugar	4.97c	15.75d
SE±		0.76	1.2
CV (%)		0.28	4.3
P-value		<0.001	<0.001

Source: modified from collected row data during the experiment

Means with the same letter(s) in column are not significant; SE± = Standard error; CV= Coefficient of variation; P-probability level

The improved fresh weight on STS-pulsed cut flowers observed in the present study is probably attributed with the improved water balance of these cut flowers, which is in turn attributed with anti-microbial activity as well as anti-ethylene synthesis ability of STS. Bettina and Neil (2005) reported the highest relative fresh weights of cut rose flowers with greatest water uptake which is also in agreement with the present findings. The findings of the present study are generally in agreement with the findings of various researchers where they found improved fresh weights of various cut flowers when pulsed with STS (Marousky, 1969; Ichimura and Suto, 1999; Prashanth, 2006). The variations of different rose varieties in their flower diameter as well as flower fresh weight observed in the present study on the other hand can be attributed with variations in their genetic makeup as indicated by Ichimura *et al.* (2005); Marandi *et al.* (2011).

The decrease in relative fresh weights during vase life observed in distilled-water pulsed cut flowers could be due to the decrease in water uptake as observed in the present study and findings of other scholars (Serek *et al.*, 1995). The decrease in fresh weight might be also attributed the reduced level of starch, cell wall polysaccharides, proteins and nucleic acid, which are occurred at petal senescence stage (Matile and Winkenbach, 1971). Ethylene also induces rapid hydrolysis of storage materials due to which heavy weight loss is noticed in cut flowers during senescence which is also in agreement with the findings observed on distilled water pulsed cut flowers. On the other hand, use of ant-ethylene solution like STS in the present study significantly reduced weight loss during senescence by checking ethylene induced hydrolysis as observed by various scholars Singh, K., P.J. Singh, and R. Kumar. 2004..

4. CONCLUSION

Prolonging the shelf life of cut flowers is the main challengs of the export-orented floriculture industry of Ethiopia which can be achieved by using appropriate preserveatives for harvested cut flower. Preservatives and rose varieties used in the present study influenced in the main as well as their interaction effects the physiological parameters and rate of senecense of cut flowers significantly. Pulsing cut rose flowers with Silver thio-sulfate recorded the best results in all evaluated parameters and followed by calcium hypochlorite. Athena variety pulsed with Silver thio-sulfate recorded the maximum water uptake (7.73 g/flower/day), transpiration loss (7.08 g/flower/day), flower fresh weight (21.77 g/flowers), flower head diameter (7.6 cm), and maximum flower vase life/longevity (23 days) during the vase life. While pulsing cut flowers with calcium hypochlorite recorded the second best results, pulsing with distilled water recorded the lowest results in most of the parameters of the tested rose varieties. Use of silver thio-sulfate and calcium hypochlorite as pulsing solutions is recommended to extend longevity or vase life of rose flowers in Ethiopia.

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