academicJournals

Vol. 4(8) pp. 111-118, December 2013
DOI: 10.5897/IJBMBR2013.0171
ISSN 2141-2154 ©2013 Academic Journals
http:// www.academicjournals.org/IJBMBR

International Journal for Biotechnology and Molecular Biology Research

Full Length Research Paper

Influence of preservative solutions on vase life and postharvest characteristics of rose (Rosa hybrid) cut flowers

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Accepted 22 September, 2013

The experiment was carried out to asses the influence of five preservative solutions (aluminium + ethanol, aluminium + sucrose, ethnol + sucrose, aluminium + ethanol + sucrose and water) and two rose cultivars ('Red Sky' and 'Blizzard'). The scope of the study was to identify the best combination of preservative solutions on rose cultivars. The treatments were arranged in factorial combination in CRD with three replications. Ten (10) cut flowers of each treatment were pre-treated using prepared preservative solution for 24 h in cold room (3 ± 1°C) before storage. Interaction effects of Preservative solutions and cultivars were significant (P < 0.05) on solution uptake on day 16; petal fresh weight on day 4; total soluble solids (TSS) on day 4, 8 and 12 and on vase solution absorbance. Preservative solutions had significant effects on solution uptake on day 1, 4, 8 and 12; TSS on day 1 and 16; petal fresh weight on day 1, 8, 12, and 16. Flower longevity and maximum flower head diameter, relative fresh weight and petal fresh weight loss were significantly (P < 0.05) reduced. Cultivars had significant (P < 0.05) difference on solution uptake and TSS. Aluminium + ethanol + sucrose preservative solution treated cut flowers had shown longest vase life, flower opening, solution uptake, petal fresh weight and TSS on both cultivars; while the values were significantly higher in 'Red Sky' cultivar. The findings provide an alternative for extending the vase life of cut roses and thereby ensure the satisfaction of flower users and sustainability of cut rose flower production.

Key words: Aluminum sulphate, ethanol, preservative solution, quality, rose, sucrose, vase life.

INTRODUCTION

About 20% of fresh flowers lose their quality while passing through the market (harvest, packaging, transportation, and sale) and a large deal of remaining flowers are sold at low quality conditions dissatisfying the consumer (Panhwar, 2006; Asfanani et al., 2008) due to physiological and pathological problems during the postharvest handling. Under normal conditions, cut flowers last only for a few days maintaining their beauty and attractiveness. However, most of the people like to enjoy them in their natural beauty and appearances for a longer period of time having the socioeconomic value of flowers intact (Tsegaw et al., 2011; Zamani et al., 2011). Thus, using appropriate preservatives could help to extend the vase life of the harvested produce for consumer satisfaction and exploitation of the business.

Short vase life of cut flowers is related to wilting, ethylene production and vascular blockage by air and microorganisms (Elgimabi, 2011). Preservative solutions are generally required to supply energy source, reduce microbial build up and vascular blockage, increase water

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uptake of the stem, and arrest the negative effect of ethylene (Nigussie, 2005). Incorporation of different chemical preservatives to the holding (vase) solution is recommended to prolong the vase life of cut flowers (Ichimura et al., 2006). However, many cut flower growers in Ethiopia rarely put energy source, such as sucrose in the solutions being prepared for post-harvest treatment (Nigussie, 2005).

In addition to this ethylene also adversely affected the longevity and quality of cut flowers; in which STS now widely used commercially to inhibit the acceleration of roses senescence by reducing ethylene related problems. However, since it contains the silver ion which is a potent environmental pollutant and its cost still the agricultural use of silver has been criticized.

Thus, alternative techniques for extending the vase life of cut flowers are commercial interest (Serek et al., 1995). Therefore, the objective of the study was to evaluate the effects of different combination of aluminum sulphate, ethanol and sucrose on 'Red Sky' and 'Blizzard' rose cultivars.

MATERIALS AND METHODS

Experimental design, treatments and procedures

The treatments were consisted of five preservative solutions tested on two rose cultivars; arranged in CRD and replicated three times.The flowers were harvested at stage 1 when the buds were tight and the sepals enclosed in the floral bud early in the morning and kept in buckets partially filled with water in upright position (Capdeville et al., 2005). Sorting and grading were done in pr-cooling room.

The preservative solutions were prepared using water and the pH was adjusted to 3.5 to 4.5 with citric acid, except that of aluminum sulphate containing preservative solution which was adjusted to a pH of 3.5, with potassium hydroxide (KOH). Then, immediately after bunches were put in buckets with concentrations of chemical solutions; 0.5 g/L aluminum sulphate, 4% ethanol and 20 g/L sucrose kept in 3 ± 1°C cooling room.

The cut flowers were placed in separate glass jars keeping the bottom of the flower stem; completely immersed in each treatment. Flower stems were cut diagonally using a sharp knife prior to immersing to facilitate absorption of the vase solution. Flowers were kept in the solution for 24 h.

A total of sixty bunches of 10 rose stems were separately soaked in to four litter of water with the respective amount of the combined five preservative solutions. Following 24 h of treatment, the lower most leaves from all flower stems were trimmed off to the height of 15 cm.

Two centimeters of the stem end was given slanted re-cut under water to get stem lengths of 48 cm. Then, the flower stems were taken out of the cold room with all the preservative solutions replaced with ready-made flower food called CHRYSAL 500 ml vase solution at a concentration of 10 g L^{-1} until the completion of the experiment.

Evaluations were made by keeping the flower stems in vase testing room at room temperature with 12 h of photoperiod using cool-white fluorescent lamps. The postharvest physiological characteristics of the flower stems were studied throughout the vase life period.

Data collected

Relative fresh weight (RFW)

Fresh weight of the flowers was determined just before the immersion of the flowers into the solutions and repeated every four days until the vase life of the flowers were terminated. Flowers were taken out of solutions for such a short time as possible (20 to 30 s). The fresh weight of each flower was expressed relative to the initial weight to represent the water status of the flower (Joyce and Jones, 1992).

$$\text{Ralative Fresh Weight} = \frac{\text{Final Weight}}{\text{Initial Weight}} \times 100$$

Solution uptake (S)

Solution uptake was determined by taking four flower stalks and subtracting the volume of water evaporated from a flask of the same volume without cut flower (Chamani et al., 2005).

$$\text{Solution Uptake} = \frac{S(t-1) - St}{\text{Initial Fresh Weight}} \times 100$$

Where, St= Solution weight (g) at time 1, 4, 8, 12 and 16 Days; St-1 = solution weight (g) of the control.

Total soluble solids (TSS)

Tissue sap was extracted from ten petals and TSS was determined using digital Refractrometer (model: RFM 840, Japan) by placing two drops of clear juice on the prism surface and reading was taken as described by Lacey et al. (2001). Data were taken at three days interval and expressed in ^{o}Brix.

Solution turbidity of microbial count assessment (VSAbs)

Solution turbidity attributable to microbial growth was assessed at the end of the experiment by measuring absorbance at 400, 500 and 600 nm with a spectrophotometer (Model: JENWAY 6300) and calculating the mean of these values using distilled water as a blank (Knee, 2000).

Petal fresh weight (PFW)

The fresh weight of each flower was expressed relative to the initial weight to represent the water status of the flower (Joyce and Jones, 1992).

Petal dry weight (PDW)

A dry weight of six outer petals was recorded using sensitive balance (Model: *SW 1S,* Germany) after drying the petals to constant weight in an oven (Model: *JM-OD16,* Japan) at 70°C.

Maximum flower head diameter (MFHD)

Flower bud diameter was measured daily with Vernier-caliper. The

Table 1. Effect of preservative solutions and cultivars on Solution uptake, RFW and TSS of rose cut flower.

Treatment	Solution uptake (ml/day/g)				RFW (%)					TSS (°Brix)	
	Vase life (days)										
	1	4	8	12	1	4	8	12	16	1	16
PS											
Al+Et	0.43	0.35^{a}	0.30^{a}	0.24^{b}	108.28^{a}	104.45^{a}	90.18^{b}	80.81^{b}	72.22^{b}	7.17^{b}	6.17c
Al+Suc	0.42	0.34^{a}	0.30^{a}	0.25^{b}	108.25^{a}	103.85^{a}	90.07^{b}	79.42^{b}	73.05^{b}	8.30^{a}	7.28^{b}
Su+Et	0.43	0.34^{a}	0.29^{a}	0.24^{b}	110.16^{a}	107.18^{a}	93.99^{b}	84.09^{b}	73.98^{b}	8.70^{a}	7.67^{b}
Al+Suc+Et	0.46	0.37^{a}	0.34^{a}	0.29^{a}	110.49^{a}	109.15^{a}	100.69^{a}	91.59^{a}	81.21^{a}	8.73^{a}	8.22^{a}
Water	0.3	0.28^{b}	0.22^{b}	0.19^{c}	103.37^{a}	95.31^{b}	83.34^{c}	70.18^{c}	-	6.72^{b}	-
$LSD_{(0.05)}$	ns	0.05	0.04	0.04	ns	6.47	5.94	7.27	5. 36	1.05	0.52
Cultivar											
'Red Sky'	0.46^{a}	0.33	0.32^{a}	0.26^{a}	107.59	103.01	90.94	81.3	76.22	8.15	7.5^{a}
'Blizzard'	0.38^{b}	0.34	0.26^{b}	0.22^{b}	108.62	104.97	92.37	81.14	74.01	7.7	7.09^{b}
$LSD_{(0.05)}$	0.05	ns	0.03	0.03	ns	ns	ns	ns	ns	ns	0.37
$CV_{(\%)}$	15.11	11.2	14.49	15.24	1	4	8	12	16	11.02	5.79

Means within a column followed by same letter(s) are not significantly different at 5% LSD test. RFW= Relative fresh weight, TSS= total soluble solid, PS= preservative solutions.

MFHD of four cut flowers were recorded using the procedure of Van Doorn et al. (1991).

Flower longevity

Flower longevity was recorded as the number of days on vase until the flowers showed symptoms of bent neck or advanced signs of fading on all petals (Liao et al., 2000).

Statistical analysis

Data were subjected to analysis of variance (ANOVA) using SAS software version 9. 2. Verification of significant differences was done using LSD test at 5% probability level.

RESULT AND DISCUSSION

Relative fresh weight

Preservative solution had highly significant ($P < 0.001$) effect on RFW of cut flowers at 4, 8, 12 and 16 days after harvesting. At 4, 8 and 12 days after harvesting, RFW of cut flowers treated with Al+Et+Suc, Al+Suc, Al+Et and Et+Suc preservative solutions were significantly higher than those treated with water (Table 1). Starting from eight days after harvesting, cut flowers treated with Al+Et+Suc had significantly higher than treated with other preservative solutions (Table 1). Cultivar had non-significant effect ($P > 0.05$) on RFW of cut flowers. Interaction effects of preservative solutions and cultivars were non-significant ($P > 0.05$) on RFW across all days of the vase life.

RFW of cut rose flowers was varied with preservative solutions. RFW was decreased with storage time in all treatments (Table 1). Cut flowers treated with Al+Et+Suc, RFW remained above 100% until day 8; with Al+Suc, Al+Et and Et+Suc remained above 100% till day 4 after harvest (Table 1). Starting from day 4, cut flowers treated with water RFW was decreased sharply (<100%). Similar findings were reported by Tsegaw et al. (2011) who found that RFW of cut flowers treated with HQS were observed to be above 100% until day 9; with other pulsing biocides and preservative solutions it remained above 100% up to day 5 vase life. In line with this, Hajizadeh et al. (2012) reported that RFW of flowers had a decreasing trend during vase life and the lowest value was observed in control at the end of vase life in Rosa hybrid cv. Black magic. The increment in RFW at initial vase life days could be due to the higher solution uptake during the early storage time as supported by Seyf et al. (2012) who found that because of more water absorption, aluminum treated flowers of cut rose 'Boeing' had more RFW than control. The declined RFW during prolonged storage time might be due to high water loss and the declining solution uptake as confirmed by Bayleyegn et al. (2012). In the current study, the best relative fresh weight maintained on cut flowers treated with Al+Suc+Et could be related to reduced microbial load in the vase solution and hence, solution usage.

Solution uptake

Interaction effect of preservative solution and cultivar on

solution uptake of rose cut flowers was significant ($p < 0.05$) on the 16thday after harvesting. On this vase life day, the highest uptake was recorded on cultivar 'Red Sky' treated with Al+Et+Suc which however, didn't statistically vary from 'Red Sky' treated with Al+Et and Et+Suc as well as the cultivar 'Blizzard'. Preservative solutions had a significant ($p < 0.05$) effect on solution uptake of cut flowers at 4, 8, and 12 days after harvesting. Solution uptake of the cut flowers treated with all preservative solutions on 4, 8 and 12 days after harvesting were significantly higher than cut flowers kept on control.

However, solution uptakes of the cut flowers in all preservative solutions on 4 and 8 days after harvesting were statistically the same (Table 1). On day 12, solution uptake of cut flowers treated with Al+Et+Suc was significantly higher than those treated with Al+Et, Al+Suc, Et+Suc and water (Table 1). Moreover, Cultivar had a significant ($p < 0.01$) effect on solution uptake of cut flowers. Mean solution uptakes of cut flowers of cultivar 'Red Sky' on the 1st, 8th and 12th days after harvesting were about 21, 23 and 18%, respectively, higher than on response dates (Table 1).

Solution uptake of cut rose flowers were depends on the type of preservative solutions and the cultivars. Generally, solution uptake decreased with increasing storage time. This could be due to air embolism of cut stem, proliferation of microbes, and plant reaction to wounding as described by Tsegaw et al. (2011). Solution uptake was recorded from cut flowers of 'Red Sky' followed cultivar treated with Al+ Et+Suc and solution uptake was observed in cut flowers of cultivar 'Blizzard' treated with the remaining preservatives (Table 1). On the other hand, the ending vase life of cut flowers treated with water on day 12 could be due to microbial development in the vase solution which might have clogged the xylem tube making the cut flower stems unable to uptake solution from the vase. Pun et al. (2003) reported that even in the flower stem that is removed from the mother plant, certain enzymes are mobilized to the wounded area where chemicals are released in order to try to seal the wound.

Similarly, Knee (2000) reported that the rates of vase solution uptake by *Gerbera* 'Monarch', *Gypsophila* 'Crystal' and *Matthiola* 'Ruby Red' stems were highly variable but generally decreased over time. Cultivar 'Red Sky' showed a higher capacity to absorb solution than the cultivar 'Blizzard' which might be due to better positive response to the preservative solutions than 'Blizzard'. This is similar to the findings of Ichimura et al. (2002) who reported different responses of rose cultivars to chemical compounds caused by genetic variations. Similarly, Nijsse et al. (2001) realized that variability among cultivars as to water uptake may be due to differences in xylem anatomy, which has been shown to greatly influence hydraulic conductivity.

Total soluble solid

Interaction effect of preservative solutions and cultivar on TSS of rose cut flowers was significant ($p < 0.05$) on day 4, 8 and 12 after harvest. On day 4 of vase life, TSS of cut flowers of cultivar 'Red Sky' treated with Al+Et+Suc significantly higher than the remaining treatments combinations. On day 8, the highest TSS value of cut rose flower was recorded in 'Red Sky' treated with water, however didn't vary from values recorded from same cultivar treated with Al+Et+ Suc and Et+Suc as well as Blizzard treated with Al+Et+Suc preservative solutions. On day 12, Al+Et+Suc treatments in both cultivars recorded significantly higher TSS compared to the remaining preservatives cultivars combinations (Table 2). Preservative solutions had significant ($p < 0.001$) effect on TSS of cut flowers on the day 1 and 16 after harvest. On day 1 of vase life, TSS of cut flowers treated with Al+Suc, Et+Suc and Al+Et+Suc preservative solutions were significantly higher than those treated with Al+Et and control; while TSS of cut flowers on Al+Suc, Et+Suc and Al+Et+Suc treatments were statistically the same (Table 1). Similarly, TSS of cut flowers treated with Al+Et and water were statistically the same. On day 16, highest TSS were recorded from cut flowers treated with Al+Et+Suc while the lowest TSS on this day was recorded on cut flowers treated with Al+Et but cut flowers treated with Al+Suc and Et+Suc had statistically the same TSS (Table 1). Cultivars had significant ($p < 0.05$) effect on TSS of cut rose flower petals on day 16. Mean TSS of cut flowers of variety 'Red Sky' on this day were 7.5 ^{o}Brix while for cultivar 'Blizzard', TSS of cut flowers were 7.5 and 7.09. But on day one, both cultivars revealed statistically the same TSS of petals (Table 1).

TSS was increased up to eight vase life days and then decreased which confirmed of Elgimabi and Sliai (2013) who reported that sugar content of roses increased at the beginning of the experiment, and then decreased towards the end. Cultivar 'Red Sky' had shown higher TSS value of petals than 'Blizzard' indicating that cultivars could vary in TSS content of cut flowers. In line with these, Tsegaw et al. (2011) reported cultivar 'Red calypso' exhibited the highest TSS value while Akito had the lowest and Viva was found to be intermediate between them. An increase in TSS at the early stage may be due to substitution of the required substrate for respiration by rapid solution uptake whereas the reduction in TSS after the 8th day of vase life may be due to the utilization of the stored food as substrate and inability to substitute it by the low solution uptake as the storage time increased.

Vase solution absorbance (VSAbs)

The interaction effect of preservative solution and cultivar on vase solution absorbance was significant ($p < 0.05$).

Table 2. Interaction effects of preservative solutions and cultivar on TSS, PFW and vase solution absorbance of rose flowers.

Treatment	Solution uptake (ml/day/g)		TSS (°Brix)						PFW (g)		Vase solution absorbance	
	Day 16		Day 4		Day 8		Day 12		Day 4		day 16	
	'Red Sky'	'Blizzard'	'Red Sky'	'Blizzard'	'Red Sky'	'Blizzard'	'Red Sky'	'Blizzard'	'Red Sky'	'Blizzard'	'Red Sky'	'Blizzard'
Al+Et	0.24^{abc}	0.15^{d}	8.37^{bc}	7.6^{bcd}	8.47^{bc}	6.6^{d}	7.73^{b}	5.87^{c}	1.53^{b}	1.47^{b}	0.050^{de}	0.052^{de}
Al+Suc	0.23^{bc}	0.20^{cd}	8.3^{bc}	8.43^{b}	9.13^{ab}	8.43^{bc}	7.63^{b}	7.40^{b}	1.40^{b}	1.50^{b}	0.059^{cd}	0.072^{ab}
Et+Suc	0.28^{ab}	0.16^{d}	9.4^{a}	8.17^{bc}	9.3^{ab}	7.6^{cd}	7.90^{b}	7.63^{b}	1.53^{b}	1.50^{b}	0.068^{bc}	0.065^{bc}
Al+Et+Suc	0.30^{a}	0.27^{ab}	9.7^{a}	7.93^{bcd}	9.67^{ab}	9.13^{ab}	9.00^{a}	8.83^{a}	1.93^{a}	1.57^{b}	0.048^{e}	0.053^{de}
Water	-	-	7.5^{cd}	7.07^{d}	7.03^{a}	7.63^{cd}	6.50^{c}	6.43^{c}	1.13^{c}	1.10^{c}	0.079^{a}	0.072^{ab}
$LSD_{(0.05)}$	0.06		0.89		1.11		0.89		0.20		0.009	
$CV_{(\%)}$	15.04		6.37		7.86		7.04		8.07		8.61	

Means within a column followed by same letter(s) are not significantly different at 5% LSD test. TSS= total soluble solid, PFW= petal fresh weight.

Accordingly, the highest (0.079) and (0.048) lowest vase solution absorbance were recorded from cultivar 'Red Sky' treated with water alone and Al+Et +Suc, respectively (Table 2). The significant reduction in vase solution absorbance of cut flowers might be due to the presence of the biocide aluminum sulphate and ethanol as disinfectant. Addition of biocide and disinfectants might have helped in suppressing microbial growth and the clear vase solution obtained in the current study could have made absorption by the cut stems easy.

In conformity with the findings of the current investigation, high absorbance values of vase solution were also reported before in the absence of biocides by Knee (2000). The present results indicated that in all preservative solutions having sucrose did not result in clearer vase solution as compared to the pure water (control); but preservatives containing aluminum sulphate and ethanol together (Al+Et and Al+Et+Suc) had significantly lower vase solution absorbance clearly indicating that sucrose helps for microbial development in the vase and resulted in poor solution uptake by stem. Therefore, the results were convinced that addition of anti microbes decreased solution turbidity which also enhanced solution usage and increased lasting life of the cut flowers.

Petal fresh weight

Interaction effect of preservative solution and cultivar on PFW of rose cut flowers was significant ($p > 0.05$) on day 4 after harvested. On this particular day, PFW of cut flowers of cultivar 'Red Sky' treated with Al+Et+Suc produced the highest (1.93) while the control in both cultivar recorded the least (1.12 g) on average PFW (Table 3). Preservative solution had a significant ($p < 0.05$) effect on petal fresh weight of rose cut flowers 1, 4, 8, 12and 16 days after harvest (Appendix 2). However, PFW of the cut flowers treated with Al+Et, Al+Suc and Suc+Et on day 4, 8 and 16 of vase life were statistically the same (Table 3). The lowest PFW on day 12 was recorded from cut flowers treated with Al+ Suc. Moreover, PFW of the cut flowers treated with Al+Et +Suc on day 4, 8, 12 and 16 were significantly higher than those treated with Al+Et, Al+Suc, Suc+Et and water (Table 3). In the case of Al+Et+Suc, the PFW increased first from day 1 to day 4 then decreased till the end of vase life period. Furthermore, cultivar had a significant effect ($p < 0.01$) on solution uptake of cut flowers. Cultivar 'Red Sky' had 13.93, 11.66, 12.30 and 8.42% greater petal fresh weight than 'Blizzard' particularly on the 1^{st}, 8^{th}, 12^{th} and 16^{th}days, respectively (Table 3).

The lowest PFW recorded in Al+Suc indicate that aluminum sulphate is not enough to act as biocide to suppress the microbial unless it is coupled with ethanol. Ethanol is a disinfectant that can enhance water conductance by preventing microbial proliferation. Hence, it could improve effectiveness of aluminum sulphate with the addition of that could be the reason for excellent maintenance of PFW of the cut flowers treated with Al+Et+Suc. These results were also related with the low solution uptake recorded on the current experiment even though it was not significant. While PFW was best maintained in Al+Et+Suc indicated that when ethanol was applied it can act as disinfectant so that enhance solution uptake then maintained PFW.

Several researches shown that the short vase life is related to rapid decline in water uptake and drying of stems (Ichimura et al, 2002; Tsegaw et al., 2011). From Nair and Sharna, (2003) point of view, all preservative solution must essentially contain two components including sugar and germicides. The current findings support this idea. Cognizant of this, van Doorn et al. (1991) reported that flowers placed in water without antimicrobial compounds had a low water potential as a result of vascular

Table 3. PFW and PDW, MFHD and flower longevity (FL) of rose cut flower as affected by different preservative solutions and cultivars.

Treatment	Petal fresh weight (g)				Petal dry weight (g)					MFHD (cm)	FL (days)
	Vase life (days)										
	1	8	12	16	1	4	8	12	16		
PS											
Al+Et	1.52^{a}	1.23^{b}	1.07^{bc}	0.72^{b}	0.18^{ab}	0.19^{ab}	0.19^{c}	0.17^{a}	0.15	7.25^{b}	15.5^{b}
Al+Suc	1.52^{a}	1.25^{b}	0.95^{c}	0.73^{b}	0.18^{ab}	0.19^{ab}	0.20^{ab}	0.16^{a}	0.15	7.46^{b}	16.0^{b}
Et+Suc	1.57^{a}	1.35^{b}	1.13^{b}	0.73^{b}	0.19^{a}	0.20^{a}	0.22^{a}	0.17^{a}	0.15	8.12^{a}	16.17^{b}
Al+Et+Suc	1.68^{a}	1.53^{a}	1.28^{a}	0.85^{a}	0.18^{ab}	0.19^{ab}	0.21^{ab}	0.16^{a}	0.15	8.21^{a}	17.67^{a}
Water	1.28^{b}	0.82^{c}	0.62^{d}	-	0.18^{ab}	0.18^{b}	0.16^{c}	0.14^{b}	-	6.06^{c}	12.33^{c}
$LSD_{(0.05)}$	0.18	0.12	0.12	0.09	0.01	0.02	0.02	0.01	ns	0.63	1.34
Cultivar											
'Red Sky'	1.63^{a}	1.31^{a}	1.09^{a}	0.79^{a}	0.18	0.18^{b}	0.19	0.16	0.16^{a}	7.07^{b}	16.06^{a}
'Blizzard'	1.40^{b}	1.16^{b}	0.93^{b}	0.72^{b}	0.18	0.21^{a}	0.20	0.16	0.15^{b}	7.78^{a}	15.0^{b}
$LSD_{(0.05)}$	0.11	0.08	0.08	0.06	ns	0.01	ns	ns	0.01	0.40	0.84
$CV_{(\%)}$	9.73	8.618	10.23	10.72	5.97	7.77	7.14	7.05	5.01	7. 02	7.14

Means within a column followed by same letter(s) are not significantly different at 5% LSD test. MFHD= Maximum flower head diameter, FL=Flower longevity, PS= Preservative solutions.

blockage in the lowermost segment of the stem. The reason for best PFW in treatment (Al+Et+Suc) could be due to the main components of preservative solution incorporated.

Petal dry weight

Preservative solution had a significant ($p < 0.05$) effect on PDW of flower petals throughout the study period. On the 4th and 8th day of vase life, flowers treated with Et+Suc had the highest PDW but not significantly different from Al+Et+Suc and Al+Suc treated flowers. On day 12, cut flowers treated with water had significantly lower PDW compared to those cut flowers treated with preservative solutions. Similarly, on day 16 there was no significant difference recorded among the different preservative solutions (Table 3). Comparing the two rose cultivars, statistically the same PDW were recorded on days 1, 8, and 12. But on day 4, petal dry weights were higher in 'Red Sky' cut flowers whereas on day 16 'Blizzard' had shown significantly higher petal dry weight. In this regard, there was no consistency.

Generally, there was no significant difference recorded on dry mater content of cut flowers treated with Al+Et and tap water. Moreover, in this experiment those cut flowers treated with sucrose containing preservative solution had shown statistically the same petal dry weight in all vase life days and significantly higher on the 8th day after harvest as compared to the control and Al+Et treated flowers. This could be due to the importance of sucrose for cell expansion and dry mater accumulation as it could help for the endogenous sucrose serve as a substrate of respiration. At 12 and 16 days after harvest PDW of cut flowers treated with sucrose containing preservative solution cut off with those Al+Et which could be due to the effects of respiration. Parallel to this, holding solution containing 8-HQS+Sucrose reduced the respiration rate and physiological loss in weight of spikes of Dendrobium hybrid Sonia-17 (Dineshbabu et al., 2002). This may be due to the solution uptake and accumulated substrate for respiration and decreased due to increment of respiration rate and reduction in substrate for respiration in storage time. In addition, in the current experiment no variation in PDW was found between the two cultivars (Table 3). PDW increased until day 8 after harvest and then decreased till the end of vase life. The rapid decrease in PDW through time could be due to the decreasing solution uptake that compensates the respiration and transpiration.

Maximum flower head diameter

Preservative solutions had significant ($p < 0.001$) effects on MFHD (Table 3). The largest (8.21 cm) and smallest (6.06 cm) MFHD were registered from cut flowers treated with preservative solution that contained Al+Su+Et and water respectively. MFHD recorded from cut flowers treated with Al+Et+Suc, Al+Et, Al+Suc and Et+Suc preservative solutions were 8.21, 7.25, 7.46 and 8.25 cm, respectively. However, the difference between Al+Et+Suc

and Et+Suc was not statistically significant. Cultivar imparted a significant ($p < 0.01$) difference on MFHD (Table 3). MFHD recorded for cultivar 'Blizzard' and 'Red Sky' was 7.78 and 7.07 cm respectively (Table 3). Interaction effects of preservative solution and cultivars on mean MFHD were non-significant ($p > 0.05$).

Treatment with Et+Suc had a pronounced effect on flower bud expansion which confirmed with idea of Sarkka (2005) who suggested that carbohydrates are necessary for turgor pressure maintenance and important energy sources facilitating flower opening. In harmony to the present results Ichimura et al. (2002) showed an increased in flower diameter was observed when 20 g of sucrose L^{-1}+200 mg of HQS l^{-1} were used in the pulsing solution, which of course varied among the varieties tested. Al+Et+Suc treated cut flowers was shown better performance in most post harvest characteristics of 'Red Sky' cut flowers than 'Blizzard'. Cultivar 'Blizzard' had better flower diameter indicating that flower diameter could also vary due to the variation in genetic makeup. In confirmation to the current experiment Ichimura et al. (2005) found that an increase in flower head diameter was observed in rose cultivars 'Sonia' and 'Delilah' than other cultivars with identical treatments.

Flower longevity

Preservative solution had significant ($p < 0.01$) effects on flower longevity of cut flowers (Table 3). Vase life of cut flowers treated with preservative solution Al+Et +Suc, Al+Suc, Et+Suc and Al+Et extended vase life of the cut flowers by 5.33, 3.83, 3.7 and 3.2 days, respectively, as compared to water treated cut flowers (Table 3). Cut flowers treated with Al+Suc, Et +Suc and Al+Et remained with acceptable display life for 16.17, 16 and 15.5 days. Cultivar had a significant effect ($p < 0.05$) on vase life of cut flowers (Table 3). The number of days where cut flowers of 'Red Sky' and 'Blizzard' remained viable was 16.07 and 15, respectively (Table 3). Interaction effects of preservative solutions and cultivars was non-significant ($p > 0.05$) effects on flower longevity.

According to Tsegaw et al. (2011) $Al_2(SO_4)_3$, which is a common biocide used in most Ethiopian cut flower growers was not able to extend the vase life of cut flower stems better than the control, treated with tap water. This evidently indicated that combined effect of the chemicals could be the reason for successful vase life extension to 17.67 days of the cut flowers via improving solution uptake, reducing RFW loss, reducing PFW loss, reducing vase and enhancing TSS observed in current study as justified by Hajizadeh et al. (2012) on rose cultivar 'Black magic'. In line with this Wu et al. (1992) reported that ethanol decreases ethylene production and/or sensitivity to ethylene and also act as an antimicrobial compound to prolong vase life of some cut flowers while sucrose can provide the energy needed to cell processes including maintain the structure and function of mitochondria and the other cellular organelles as reported by Capdeville et al. (2005).The longer vase life which occurred in 'Red Sky' than 'Blizzard' which confirmed by Butt (2005) suggested that variation on vase life could be due to their genetic variability and different responses to chemical compounds. Varieties could also be varying in lasting life due to ethylene production and sensitivity as well as resistance to different disease causing microorganisms (Ichimura et al., 2002).

Conclusion

The best flower longevity, MFHD and lowest vase solution absorbance was maintained due to the treatments of Al+Et+Suc preservative solution and the lowest vase life and MFHD was recorded from cut flowers treated with water. Treatment of the cut flowers using Al+Et, Al+Suc, Suc+Et, and Al+Et+Suc extended the vase life of the cut flowers by 3.2, 3.7, 3.83 and 5.33 days, respectively than control. Generally, it can be concluded that use of Al+Et+Suc preservative solution for flower longevity and maintaining post-harvest characteristics of cut flowers is important for 'Red Sky' and 'Blizzard' cut flowers.

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