Aluminum Sulfate as Pulsing Preservative for Export-oriented Rose Flowers under Bahir Dar Conditions, Northwestern Ethiopia

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Abstract

Rose is one of the most important cut flowers in Ethiopia produced mostly for export markets. Maintaining the postharvest life is the most challenging issue for most of the floricultural enterprises in the country. Two sets of experiments were therefore conducted in Tana Flora PLC farm, one of the biggest cut rose producers in Bahir Dar, Northwestern Ethiopia with the objectives of identifying the appropriate concentration of aluminum sulfate as pulsing preservative to maintain the vase life of export oriented rose flowers. In the first set, aluminum sulfate alone and in combination with calcium hypochlorite at different concentrations including the experience of Tana Flora PLC, sucrose and distilled water as control were tested for their influence on physiological status of `Maracuja` rose flowers. In the second set, the best performed pulsing preservative (aluminum sulfate alone) was tested at four concentrations (0ppm, 125ppm, 250ppm and 375ppm) to identify the optimum concentration. After pulsing for about 30 hours, six cut flowers were put in 250 ml glass flask containing distilled water. The flasks with flowers were arranged in Complete Randomized Design with three replications and kept in vase life testing room of Tana Flora PLC. According to the results obtained, aluminum sulfate at the concentration of 250ppm was the best in prolonging the vase life, in producing bigger flower head and maintaining the freshness of flowers. The reduction in percent fresh weight during the vase life of flowers was minimal in 250ppm aluminum sulfate pulsed flowers. The prolonged vase life of aluminum pulsed flowers is due to better water uptake and thus stabilized water balance in the flowers as observed in this study. Thus, it is advised to incorporate aluminum sulfate in flower holding solution at the concentration of 250ppm to maintain the freshness and vase life of export oriented rose flowers and those for local market in the study area.

Key words: cut rose, fresh weight, transpiration rate, water balance, water uptake

1. Introduction

Rose (*Rosa hybrida* L.) belongs to the family *Rosaceae* under which more than 150 species and 1400 cultivars are consisted (Elgimabi, 2011). Rose is one of the most popular cut flowers and has been used as garden plant since the dawn of civilization. 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 (Synge, 1971; Zlesak, 2006). Throughout the history of civilization, no other flower has been so immortalized and integrated into daily life as the rose. It plays a unique role in various occasions such as Mother`s Day, St Valentine's Day, birth and even death (ProFlower, 2012). Thus, rose is regarded as the queen of flower (Synge, 1971).

The floriculture sector in Ethiopia is flourishing from year to year. The number of flower exporting farms as well as the types of flowers exported is in increasing trend (Van der Maden *et al.*, 2011). However, roses accounted more than 80% of the cut flower production and the floriculture cultivation area in the country. Other floricultural crops such as chrysanthemums, poinsettia and geranium, and bouquet fillers primarily hypericum, carnation, gypsophila, allium and carthamus are also produced in Ethiopia (EHPEA, 2008). Ethiopia is one of the top five flower supplies in European market including Kenya, Ecuador, Columbia and Israel and holds an impressive second place among Dutch auction suppliers. The share of Ethiopian flowers in European exports doubled from 6% in 2005 to 12% in 2010 (Van der Maden *et al.*, 2011). Many varieties of the so called Hybrid Tea, Intermediate and Sweetheart roses are now produced in modern greenhouses which are mostly concentrated around Addis Ababa, the capital city of Ethiopia (Van der Maden *et al.*, 2011). Recently however, floricultural enterprises are also established and developed in other parts of the country like Bahir Dar and Hawassa.

A very important challenge of any floricultural enterprise is maintaining the harvest quality of flowers as long as possible. As flowers are harvested, they are literally cut off from their source of life. As living organism however, they respire and transpire after harvesting. As a result, water will be lost and nutrients will be broken down that in turn accelerate the aging process and reduce the vase life of cut flowers including roses (Van der Maden *et al.*, 2011). The main reason for senescence of cut flowers is wilting due to which the floral axis bent just below the flower head which stops the water supply to the flowers (Van Doorn and De-Witte, 1997). The reduction of water supply is mostly attributed by physiological occultation by plant itself, air embolism or microorganisms which plug the stem xylem vessels of the flowers (Van Doorn and De-Witte, 1997; Loubaud and Van Doorn, 2004; Särkkä, 2005; Elgimabi, 2011).

As cut roses are harvested at bud stage, they require nutrients to open. Ichimura *et al.* (2003) in their experiments were able to improve the bud opening and extend the vase life by using sucrose as source of nutrients for cut roses. An experiment done by Lutz and Hardenburg (1968) revealed that the cut flower should be in a healthy condition and should be free from any damages to avoid entry point for decaying microorganisms.

To prolong the postharvest life of cut flowers, various preservative solutions have been recommended by researchers. Such preservatives delay senescence and extend the vase life of cut flowers. Moreover, they prevent ethylene synthesis and pathogen development which shorten the vase life of flowers including roses (Halevy and Mayak, 1981; Gerailoo and Ghasemnezhad, 2011).

According to Ichimura *et al.* (2006), aluminum sulfate ($Al_2(SO_4)_3$) has been recommended to prolong the vase life of several cut flowers and is used as an antimicrobial compound in commercial preservative solutions. The compound acidifies vase solution, diminishes bacterial proliferation and enhances water uptake (Liao *et al.*, 2000; Hassanpour *et al.*, 2004; Tsegaw *et al.*, 2011) and can be used alone or in combination of sucrose (Hussen and Yassin, 2013). According to Seyf *et al.* (2012), aluminum sulfate concentrations ranging from 150 to 300 mg l^{-1} of solution have a positive effect on the vase life of cut roses. 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 (De Stigter, 1981; Nowak and Rudnicki, 1990). Silver thiosulfate (STS) is also known to suppress autocatalytic ethylene production by inhibition of ethylene action (Liao *et al.*, 2000; Butt, 2003; Da Silva, 2003; Subhashini *et al.*, 2011).

Although increased trend both in production and foreign exchange earnings (EHPEA and EHDA, 2011; MoTI, 2014), no researches have been conducted in identifying suitable preservative solution to reduce postharvest losses on floricultural crops in the country. On the other hand, since roses are mainly produced for export market, it has been experienced a very high postharvest losses which impact the foreign exchange earnings of the country negatively. Therefore, the aim of this study was mainly to evaluate pulsing preservative solutions on vase life of rose and to identify and advise the best performed preservative for reduction of postharvest losses of export oriented rose flowers.

2. Materials and Methods

2.1 Description of the study area

The experiments were conducted in December 2015 in vase life experimental room of Tana Flower PLC Bahir Dar, Ethiopia, which is one of the biggest producers and exporters of cut roses in the country. The site is located at 11.710 N latitude and 37.30 ^{0} E longitude. The altitude of the site is about 1850 m above sea level and the average annual rainfall and relative humidity are about 1250 mm and 65%, respectively. The minimum and maximum temperatures of the study site during the experimental period were about 10.5^{0}C and 27^{0}C, respectively.

2.2 Experimental materials and preservative solutions

The study was conducted in two sets of experiments. In the first set, the effects of five pulsing preservative solutions including distilled water as control were evaluated on vase life of rose variety `Maracuja`; which is a dominant rose variety produced in Tana Flora PLC. Pulsing preservative used by Tana Flora PLC for cut roses was also included in the experiment which is represented by treatment four (T4) of this experiment (Table 1). In the second set of the experiment, the best performed pulsing preservative (aluminum sulfate) was tested in four concentrations (0ppm 125pmm, 250ppm, 375ppm) to identify the optimum and area specific concentration of aluminum sulfate which prolog the vase life of rose flowers.

Table 1: Pulsing preservative solutions used in the first set of the experiment

Treatment	Pulsing preservatives & their concentrations
T1	Distilled water as control
T2	$Al_2(SO_4)_3$ (250ppm)
T3	$Al_2(SO_4)_3$ (250ppm)[b] + $Ca(ClO)_2$ (66.7ppm)[c]
T4[a]	$Al_2(SO_4)_3$ (666.7ppm) + $Ca(ClO)_2$ (66.7ppm)
T5	Sucrose (20 g l^{-1})

[a] Concentration used by Tana Flora PLC; [b] Aluminum sulfate; [c] Calcium Hypochlorite

2.3 Handling of experimental materials and pulsing procedures

Matured and uniform sized rose buds with enclosed sepals having about 60 cm stem length were harvested early in the morning, trimmed to 10 cm under water to avoid water embolisms. All leaves on the lower section of the flower stems were removed and put immediately in uniform shaped and sized flower buckets containing the pulsing preservative solutions. The amount of preservative solutions in the flower buckets was determined in such a way that about 15 cm of the rose stem cuttings were covered with pulsing solutions.

For the purpose of field heat removal, flower buckets containing the pulsing preservatives and rose stem cuttings were placed in pre-cooling room having a temperature of about 8-10 ^{O}C for about 6 hours. After field heat removal, the old preservative solutions were replaced by the new once having the same concentration and amount. Flowers were then transferred into cold room with about 2 ^{O}C room temperatures for about 24 hours for final cooling.

After cold room, the pulsing preservatives in flower buckets were replaced with distilled water and six rose flowers were put into 250 ml experimental flasks containing distilled water and transferred into vase life experimental room of Tana Flora PLC with temperature ranging from 22-25^{0}C and relative humidity of 65-70%. The pulsing procedures followed in this study resemble the practices of Tana Flora PLC for export rose flowers. The flasks containing six rose flowers each were arranged in complete randomized design (CRD) with three replications on working table. At the time of transfer to the experimental flask about 2 cm long stem was cut off at the bottom to improve transport of water through the flower stem.

2.4 Determination of physiological status of flowers and analysis

Fresh weight of flower stems (g/plant): The flask was weighed with flask + solution + flowers and weight of flask and solution was subtracted the difference in the weight signifies fresh weight of flowers. This process was repeated everyday and weight per flower stem was computed.

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

Transpiration loss (g/flower)**:** flowers were weighted daily along with solution and flowers, the consecutive difference in weights represent the (existence of) transpiration loss.

Water balance**:** Water balance was calculated by subtracting the total transpiration loss from water uptake.

Flower head diameter (cm): The diameters of four randomly selected flower buds at full bloom were measured at the center using caliper and the mean values were used for analysis.

Vase life (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 as described by Lama et al. (2013). At this point discoloration and loss of petals were started (Halevy and Mayak, 1981; Liao *et al.*, 2000). 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 soft ware version 9.1.3. Whenever the ANOVA results showed significant difference among treatments, mean separation was further performed using least significant difference (LSD**)** at 1% or 5% significance level.

3. Results and Discussion

3.1 Physiological status of rose flowers as affected by pulsing preservatives

Water uptake

It is known that cut flowers continue to loss water through transpiration, which leads to wilting. However, when cut flowers are able to absorb water, their water balance can better maintained and thus their freshness and vase life will last longer (Reddy and Singh, 1996). Although there was slight water balance reduction, flowers pulsed with Aluminum sulfate (T2) was better maintained followed those pulsed with T3 compared to other pulsing preservatives as indicated in Figure 1.

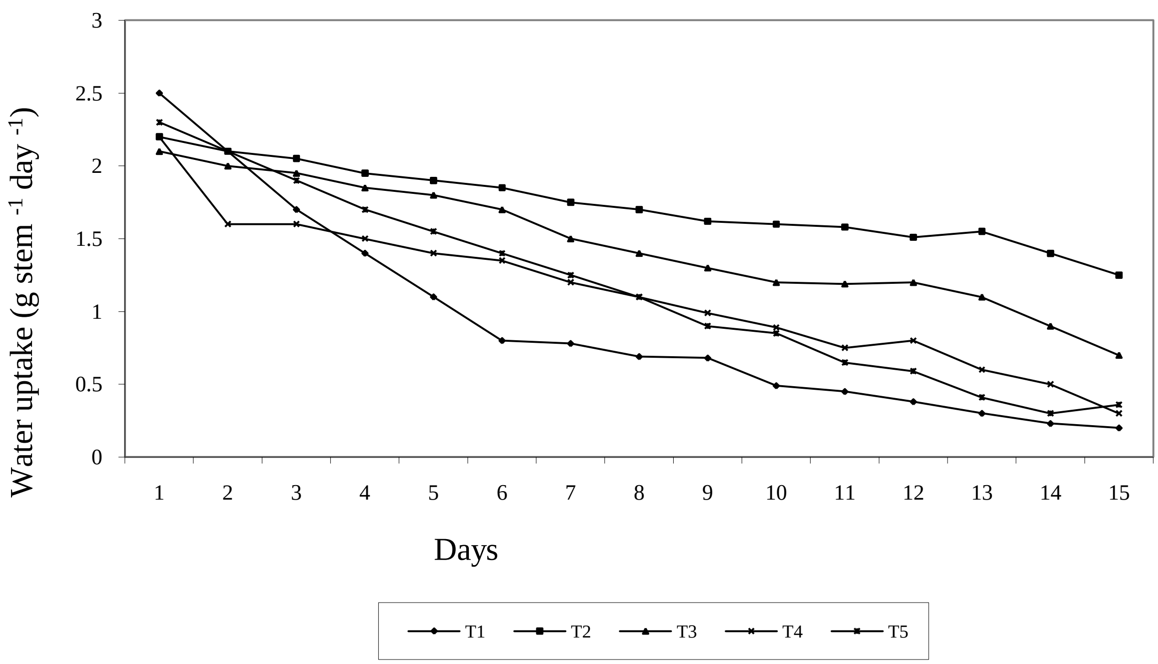

Figure 1: Effect of different pulsing preservatives on water uptake of rose flowers var. Marcuja during the vase life

T1 = distilled water; T2 = 250 ppm $Al_2(SO_4)_3$; T3 = $Al_2(SO_4)_3$ (250ppm) + $Ca(ClO)_2$ (66.7ppm); T4 = $Al_2(SO_4)_3$ (666.7ppm) + $Ca(ClO)_2$ (66.7ppm); T5 = Sucrose (20 g l^{-1})

Water loss through transpiration

According to Halevy (1976) wilting which caused by loss of water is the most common reason for termination of vase life of cut flowers. Moreover, wilting is occurred when water loss through transpiration exceeds the rate of water uptake through cut flowers. As indicated in Figure 2. Aluminum sulfate sustained stable transpiration rate of cut flowers compared to other pulsing preservatives.

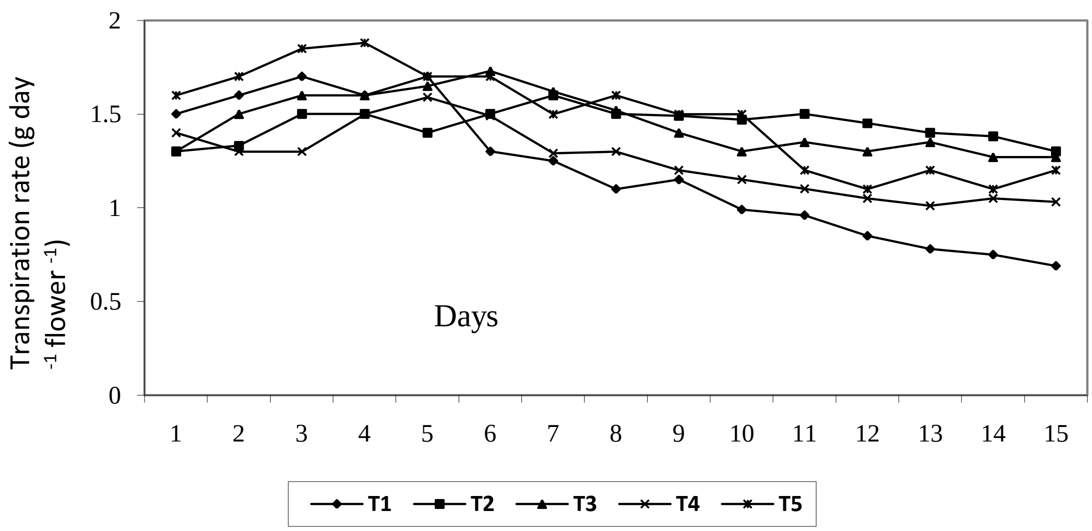

Figure 2: Effect of different pulsing preservatives on transpiration rate of rose flowers var. Marcuja during the vase life

T1 = distilled water; T2 = 250 ppm $Al_2(SO_4)_3$; T3 = $Al_2(SO_4)_3$ (250ppm) + $Ca(ClO)_2$ (66.7ppm); T4 = $Al_2(SO_4)_3$ (666.7ppm) + $Ca(ClO)_2$ (66.7ppm); T5 = Sucrose (20 g l^{-1})

Water balance

In this study, water balance of the cut flowers was determined by the difference between water uptake and water loss as indicated by Halevy and Mayak (1981). According to the author He et al. (2006) wilting is considered as termination of vase life in many flowers which is mostly caused due to water stress than natural senescence. On the other hand, the quality and longevity of cut flowers including roses is determined by water balance, which is influenced by uptake and respiration of cut flowers (Da Silva, 2003). Accordingly, wilting of cut flowers is commonly occurred when the loss of water of cut flowers through transpiration is greater than the volume of water taken by cut flowers (Halevy and Mayak, 1981). The results in Figure 3 indicated that the water balance of rose flowers, which were pulsed by aluminum sulfate (T2), showed the least negative water balance followed by T3, which confirmed relatively balanced rates of uptake and respiration of water during their vase life.

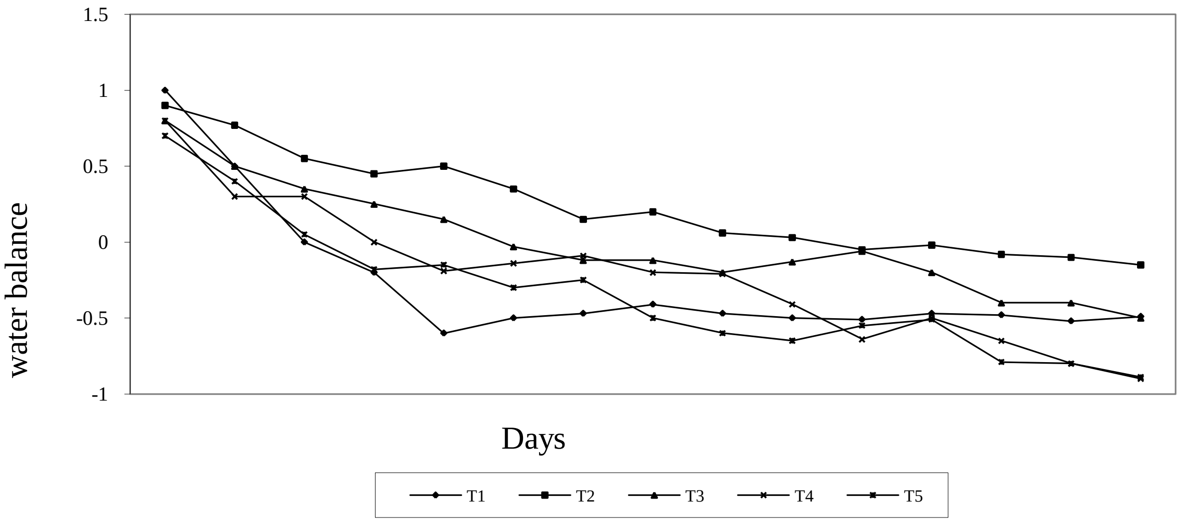

Figure 3: Effect of different pulsing preservatives on water balance of rose flowers var. Marcuja during the vase life

T1 = distilled water; T2 = 250 ppm $Al_2(SO_4)_3$; T3 = $Al_2(SO_4)_3$ (250ppm) + $Ca(ClO)_2$ (66.7ppm); T4 = $Al_2(SO_4)_3$ (666.7ppm) + $Ca(ClO)_2$ (66.7ppm); T5 = Sucrose (20 g l^{-1})

Flower weight percentage

Flower weight was assessed daily. Accordingly, the percentage decrease in flower weight was minimal in aluminum sulfate pulsed rose flowers followed by those pulsed with treatment T3, which was relatively stable up to 11th day when compared with other preservatives as well as control treatment (Figure 4).

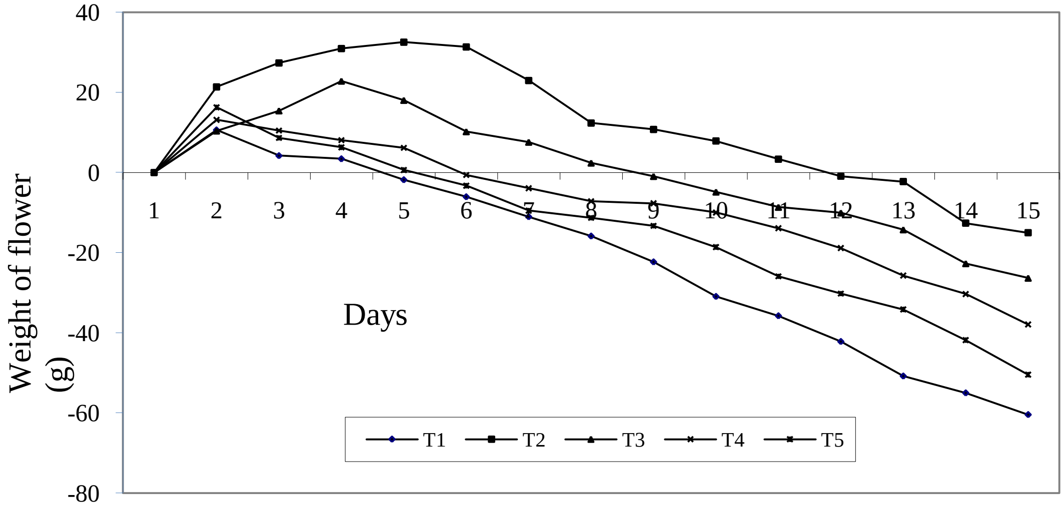

Figure 4: Effect of different pulsing preservatives on percentage of fresh weight loss during the vase life of rose flowers var. *Marcuja*

T1 = distilled water; T2 = 250 ppm $Al_2(SO_4)_3$; T3 = $Al_2(SO_4)_3$ (250ppm) + $Ca(ClO)_2$ (66.7ppm); T4 = $Al_2(SO_4)_3$ (666.7ppm) + $Ca(ClO)_2$ (66.7ppm); T5 = Sucrose (20 g l^{-1})

Vase life

The vase life of the cut rose flowers was determined by the number of days in which 50% of the flowers in the flask were bent over. According to the results, vase life of rose flowers pulsed with aluminum sulfate alone (T2) and treatment T3 were extended up to 14 and 9 days, respectively (Table 2). The vase life of control cut roses (T1) as well as those pulsed with treatment T4 and T5 were generally low compared to those pulsed with other pulsing preservatives. The extended vase life of those flowers is obviously associated with the stable water balance in aluminum sulfate pulsed cut flowers. The stable water balance on the other hand is probably due to the antimicrobial effect of aluminum sulfate, which reduced the proliferation of bacteria in vase solution responsible for blockage xylem and thus reduction of vase life (Van Doorn, 1997; De Stigter, 1981; Van Doorn *et al.*, 1990; Liao et al.2000, He et al., 2006). Application of aluminum sulfate in vase solutions has been also reduced bacterial blockage of xylem vessel of cut flowers in the findings of various researchers (Liao *et al.*, 2000; Tsegaw et al., 2011; Seyf *et al.*, 2012; Hussen and Yassin, 2013).

Moreover, buildup of antimicrobial compounds like metal salts from aluminum sulfate prevent and/or slowdown bacterial growth and ensure proper water uptake and thus delay senescence and prolong the vase life of cut flowers (Liao *et al.* (2000) and Särkkä (2005). Furthermore, aluminum sulfate acidifies the vase solutions and diminishes bacterial growth (Liao *et al.*, 2000; Hassanpour *et al.*, 2004) and acts as a bacterial filter by forming Al $(OH)_3$ sediment on the cut surface of stem (Henriette and Clerkx, 2001). However, use of highly concentrated aluminum sulfate may reduce the vase life of cut flowers as observed in treatment T4 of this study, which is also indicated by Lama *et al.* (2013).

The reduced vase life on sugar pulsed cut flowers in this study may be associated with the proliferation of bacterial growth in sugar solution which cause plugging of vascular vessels and reduction of water uptake and thus acceleration of flower senescence as observed by Ichimura, 2003; Pun and Ichimura, (2003) and Särkkä, 2005. In this regard, Ichimura *et al.* (2003) obtained reduced vase life of flowers due to high bacterial growth in sucrose solution. Therefore, they advised the use of sucrose preservatives in combination of chemicals having antimicrobial effects.

Table 2: Effect of different pulsing preservatives on percentage wilted Maracuja variety of rose flowers during vase life (days)

Treatment	Percentage wilted flowers														
Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
T1	0	0	5.6	27.8	55.6	77.8	100	100	100	100	100	100	100	100	100
T2	0	0	0	0	0	0	0	0	0	16.7	27.8	33.3	38.9	44.4	61.1
T3	0	0	0	0	5.6	11.1	22.2	27.8	33.3	50	66.7	100	100	100	100
T4	0	0	0	11.1	16.7	27.8	38.9	55.6	66.7	88.9	100	100	100	100	100
T5	0	0	5.6	5.6	22.2	38.9	44.4	61.1	72.2	100	100	100	100	100	100

T1 = distilled water; T2 = 250 ppm $Al_2(SO_4)_3$; T3 = $Al_2(SO_4)_3$ (250ppm) + $Ca(ClO)_2$ (66.7ppm); T4 = $Al_2(SO_4)_3$ (666.7ppm) + $Ca(ClO)_2$ (66.7ppm); T5 = Sucrose (20 g l^{-1})

3.2 Flower head diameter, fresh weight and vase life of rose flowers as affected by aluminum sulfate concentrations

In the first set of the experiment aluminum sulfate with the concentration of 250ppm alone was the best pulsing preservative that maintains the vase life of rose flowers as long as possible. The purpose of the second set of the experiment was to determine the optimum aluminum sulfate concentration specific to the conditions prevailed in the study area, as the concentration of aluminum sulfate used in the first set was obtained from research results done elsewhere.

Flower head diameter

Rose flowers, which are destined for export market, are mostly harvested as matured bud with enclosed sepals. The flower head diameter measured at the time of full bloom was larger in rose flowers pulsed with 250 ppm concentration of aluminum sulfate compared to other concentrations (Figure 5). The improved flower head diameter is probably associated with improved water uptake and thus better water balance of the flowers as indicated in the first experiment of this study.

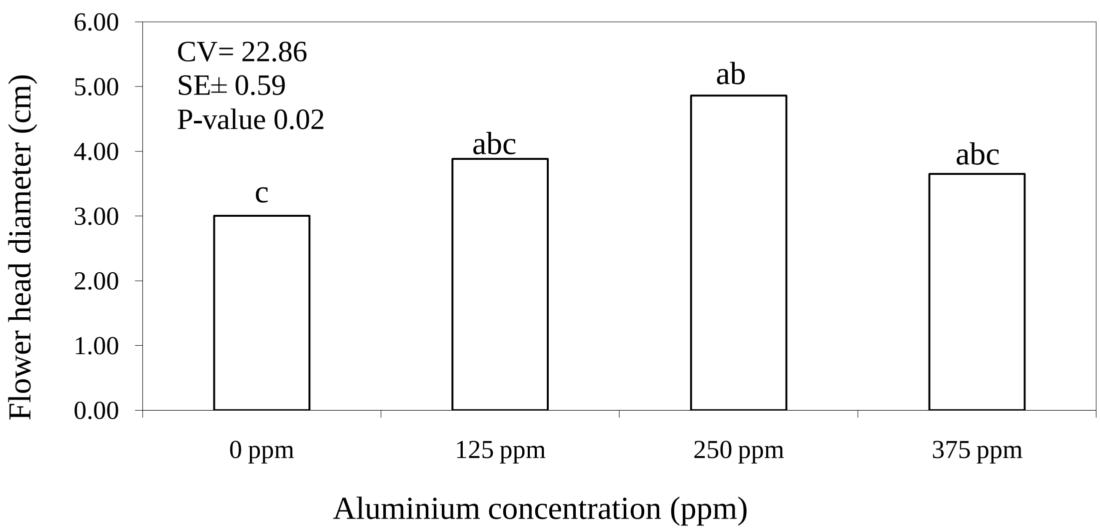

Figure 5: Effect of different rates of aluminum sulfate on flower head diameter of rose flowers var. *Marcuja* at full bloom

CV = Coefficient of variation; SE± - Standard error; P-value = probability value; Means following with the same letter(s) are not statistically different

Generally, the tested aluminum sulfate concentrations have positive effects on both vase life and fresh weight of Marajuca flowers (Table 3 and Figure 6). Rose flowers pulsed with 250 ppm concentration aluminum sulfate maintained their vase life to more than 13 days. The vase life of rose flowers pulsed with 125 ppm and 375 ppm of aluminum sulfate prolonged to more than 10 and 9 days, respectively; while those pulsed with distilled water terminated their vase life in about 4 days.

Reduction of fresh weight resulted from reduced water uptake is the sign of vase life termination in cut flowers. The fresh weight of rose flowers pulsed with 250 ppm of aluminum sulfate was significantly higher than those rose flowers pulsed with other concentrations as indicated in Figure 6. The results of this study showed that aluminum sulfate at the concentration of 250 ppm maintained the freshness and thus prolonged the vase life of Maracuja rose flowers; which is similar as the results obtained in the first set of the experiment. In agreement with these findings, Ichimura *et al.* (2006) and Särkkä (2005) reported that aluminum sulfate with the concentration of 250 ppm gave the longest vase life of rose flowers. Similarly, the longest vase life of various varieties of rose flowers was observed by the application of 250 ppm aluminum sulfate in the findings of various researchers (Seyf *et al.*, 2012; Hussen and Yassin, 2013; Lama *et al.*, 2013).

Table 3: Effect of aluminum sulfate concentration on percentage wilted rose flowers var. *Maracuja* during vase life (days)

Treatment	**Percentage wilted flowers**														
	Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0ppm		0	0	11.1	33.3	61.7	88.9	100	100	100	100	100	100	100	100	100
125ppm		0	0	0	0	0	0	0	5.6	16.7	27.9	55.6	66.7	94.4	100	100
250ppm		0	0	0	0	0	0	0	0	0	0	0	22.2	38.9	55.6	77.8
375ppm		0	0	0	0	0	0	5.6	16.7	33.3	61.1	83.3	100	100	100	100

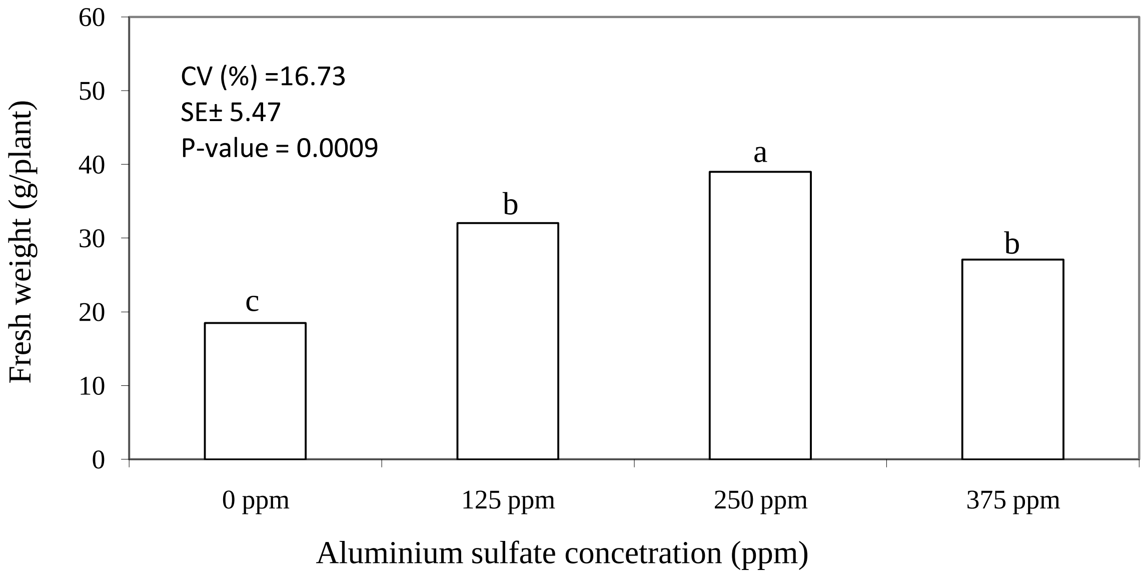

Figure 6: Effects of aluminum sulfate on fresh weight of rose flowers var. Maracuja during the vase life (14 days after pulsing

CV = Coefficient of variation; SE± - Standard error; P-value = probability value; Means following with the same letter(s) are not statistically different

4. Conclusion

The results of the present study showed that pulsing with appropriate preservative solutions maintained the freshness of rose flowers as long as possible and prolonged their vase life. Rose flowers pulsed with aluminum sulfate at concentration of 250 ppm prolonged their vase life for more than 13 days and produced bigger flower heads compared to other concentrations of aluminum sulfate. Moreover, percent in reduction of fresh weight of those flowers pulsed with 250 ppm of aluminum sulfate was minimal compared to those pulsed with other preservatives during vase life which was due to better water uptake and thus stabilized water balance. Based on the results, it is advised to incorporate 250 ppm of aluminum sulfate holding solution at production phase to maintain vase life and freshness of export oriented-rose flowers as well as those for local market.

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