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| RESEARCH ARTICLE

Effects of Plant Growth Regulators on Quality, Quantity and Vase-life of Rose flower (*Rosa hybrida* cv. Avalanche)

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| ABSTRACT
An experiment was conducted to find the appropriate material for increasing the quantitative and qualitative traits in the pre, and postharvest vase-life of the cut rose flower cv. "Avalanche" in a hydroponic greenhouse based on a randomized complete block design (RCBD) with 16 treatments and 3 replications. Treatments included gibberellic acid at four levels (0, 100, 200, and 300 ppm) and salicylic acid at four levels (0, 100, 150, and 200 ppm). The foliar application was carried out before harvest in tree time at intervals of 10 days .The results showed that the treatments had a significant effect on qualitative, quantitative, and vase life. The highest stem diameter (6.08 mm), flower length (55.90 mm), and the number of branches per plant (6.53 branches per plant) was obtained from T_4 (300 ppm gibberellic acid). The highest vase life (7 days) was recorded in T_5 (150 ppm salicylic acid), with more water absorption and a higher relative fresh weight. T_3 (200 ppm gibberellic acid) had a maximum flower diameter (36.33 mm), and T_{16} (200 ppm salicylic acid + 300 ppm gibberellic acid) had the longest stem length (74.37 cm). The desired growth regulators in different concentrations were able to increase the quantitative, qualitative, and vase life of the rose flower.

| KEYWORDS

Stem diameter, Stem length, Gibberellic acid, Salicylic acid and Vase-life

| ARTICLE INFORMATION

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1. Introduction

The floriculture industry is one of the most profitable agricultural industries in the world. Rose Flower (*Rosa hybrida* L.) is a plant of the Rosaceae family and native to various parts of the northern hemisphere. The variation of growth forms in roses is very high and ranges from miniature roses to shrubs with a growth potential of more than 15 meters (Dole and Wikins, 2005). Rose flower is the world's largest producer of cut flowers and has the highest trade among cut flowers. The appearance, quality, and vase-life of plants depend on the conditions of their cultivation, the correct harvest time, and postharvest care. One of the problems in the industry of production, marketing, and trade of roses, is a low quality and low vase-life of roses. Despite the extensive research that has been done in this area, extensive research has not yet been conducted on a number of cultivars that have low quality and quantity. In this experiment, according to the research conducted in the field for increasing the qualitative and quantitative indicators and the vase-life of rose flower, cv. "Avalanche" cultivar has been used to find the most effective combination of substances such as gibberellic acid and salicylic acid. Gibberellins belong to a large group of natural compounds called diterpenoids, which are made up of units called isoprene derived from malonic acid. Decreased levels of gibberellin have been reported in the aging process or before that in a number of tissues. In all tissues where the amount of gibberellin decreases during the aging process, the use of exogenous gibberellin will delay the aging process (Artica, 1996). Gibberellin added to the plant increases the size of the plant, and gibberellic acid, by absorbing through the stem, affects the flowering life of the rose flower cv. "Mercedes" and also this growth regulator can delay the aging of petals in different cultivars of roses without the use of sucrose in the preservation solution (Goszynask and Rudnick, 1990). After reviewing the results of the research conducted in this regard, I

came to the conclusion that growth regulators (gibberellic acid and salicylic acid) were used alone in different concentrations, while in this study, I wanted to investigate the single and combined effects of these hormones. This experiment is to investigate the effects of gibberellic acid and salicylic acid on the postharvest quality, quantity, and vase-life of the rose flower cv. "Avalanche", which is one of the most famous commercial cultivars of cuttings roses. The study was carried out in 2020 in a hydroponic greenhouse in Mashhad province in Iran.

2. Literature Review

The longest stem length and intercellular length were obtained in the rose flower "Iceberg" with foliar application of gibberellic acid (Prashanth, 2003). Gibberellic acid increased stem length, internode, and prematurity in tulips (Shakarami et al., 2013). Gibberellic acid significantly increased the number of branches, plant height, stem diameter, and the number of flowers per plant in the rose flower (Kusumawati et al., 2015). In an experiment, the results showed that gibberellic acid increased height, number of flowering days, number of flowers per plant, flower diameter, flower length, and stem length in the rose flower cv. "Grand Gala" (Rajesh, 2012). Salicylic acid is also known as a regulator of plant growth, and this hormone has been used in many physiological processes of plants such as photosynthesis, respiration, evaporation, transpiration, increasing the size of garlic, potato production and synthesis of metabolites and other enzymes (Klessig and Malamy, 1994 & Shakirova et al., 2003). Salicylic acid has been shown to be an important hormone due to its important role in regulating plant metabolism, such as regulating growth and responding to environmental stresses. Also evident in the uptake and transport of ions, rate of photosynthesis, stomatal conduction, and transpiration (Tehranifar et al., 2013). Salicylic acid can improve water absorption, flower vase-life, and oxidative enzyme activity (Alaey et al., 2011). The longest vase-life was achieved by spraying salicylic acid before harvest (Hashemabadi and Zarchini, 2010). The use of salicylic acid before the rose harvest improves the quality and quantity of the rose (Tabebzadeh et al., 2015).

3. Methodology

The present experiment was performed in the form of a randomized complete block statistical design with 3 replications and 16 treatments. Each replication of the experiment consisted of 16 pots, and each pot consisted of 12 rose bushes in two rows. Each row consisted of 6 flowering plants at a distance of 15 cm from each other with an age of approximately two years in a bed of 70% perlite and 30% coco peat. The length of the day during the plant growth period was about 15 hours, the day and night time temperatures respectively were 25-30 and 17-16°C, and the greenhouse moisture was between 50-60%. Forty-eight pots were selected for the experiment and thoroughly pruned. Of each pruned pot, only 4 plants were considered as experimental samples, and ten days after pruning, with the emergence of the first buds, a solution of growth regulators was prepared and sprayed three times at intervals of 10 days. After performing the foliar application steps, as the flowers were ready for harvest, traits such as flower diameter, stem diameter, flower length, stem length, and to know the number of flower branches per plant, all flower branches of a flash were recorded until the end of the flowering period. To measure postharvest traits, three flower branches were harvested from each replication, placed in ordinary water, and transferred to the ornamental plants' laboratory of the Ferdowsi University of Mashhad, Faculty of Agricultural Sciences. In the laboratory, two upper leaflets, except the thorns and leaves, were eliminated. Then the bottom of the stem was cut obliquely with disinfected pruning shears so that the height of the branches reached 40 cm. The branches were randomly placed in bottles containing distilled water (1000 ml), and the desired traits were measured daily. The laboratory had conditions such as temperature around 29-26°C, relative humidity of 30-35%, and 15hour light with 12foot candles. When the flowers were ready for harvest, the branches were harvested daily, and immediately the traits like flower diameter, stem diameter (largest and smallest diameter) with a simple Vernier Caliper, flower length (from the end of the petiole to the end of the petal) and the stem length (from the top of the first node to the end of the pedicel) are measured by a ruler, and this process continued until the last flowering of a flash and the values obtained were used as the main indicator in subsequent calculations (Hashemabadi, and Zarchini, 2010 & Saifuddin et al., 2009). To determine the number of flower branches per plant, the number of flower branches per plant was recorded from each replication to the end of flowering of a flash, and to determine the end of flowers' vase-life, the appearance of the flowers was checked daily, and scores were given until the flowers reached one of the ends of life criteria. Observing one of the anomalies such as withering, shedding, or browning of 5 outer petals, reduction of freshness and marketability, bending of the neck of the flowers, or appearance of any morphological anomaly were considered as the end of life criteria of cut flowers (Hassani and Alimirzaii, 2017; Alaey *et al.,* 2011; Chamani et al., 2005; Jowkar et al., 2012; Zamani et al., 2011). To know the amount of water absorption by flowers, the difference between flower weight without flowers on the first day and the last day of vase-life was calculated, and to prevent evaporation after placing the branches in the bottle, the top of the bottle was closed with glue. The following formula has been used to calculate the amount of water absorption during the shelf life of three flower branches (Jowkar et al., 2012).

Water Uptake (g) = V_1-V_2

V1 = the weight of the first day of the bottle with water

V2 = the weight of the last day of the bottle with water

The relative fresh weight (RFW) was obtained by dividing the everyday flowers weight by the weight of the zero day (test start day) and using the following formula to calculate (Liu *et al.,* 2009).

RFW (% of the initial) = $(w_t/w_{t0}) * 100$

W_t = weight of flower branches (g) per everyday (1, 2, etc.)

W_{t0} = weight of flower branches (g) on zero day

Pre and postharvest recorded data were analyzed by using $JAMP_9$ software, tables drawn with Excel-2013, and a comparison of averages was performed at $P \leq 0.05$ probability level based on the LSD test.

4. Results

Statistical analysis showed that the effect of treatments on all traits was significant. The effect of the block was significant on flower diameter, flower length, and stem length and not significant for other traits (Table 1 and 2).

Table 1: Variation analysis of pre-harvest traits of the rose flower cv. "Avalanche"

Mean Squares						
Source of Variation	**df**	**Flower diameter (mm)**	**Stem diameter (mm)**	**Flower length (mm)**	**Stem length (cm)**	**No. Flower per branch**
Block	2	28.64**	0.23ns	57.93**	76.96*	0.63ns
Treatment	15	10.48*	0.21*	14.84*	54.44**	1.21*
Error	30	4.64	0.1	5.82	19.3	0.52

**, * and ns: Significant in 0.01, 0.05 and non-significant, respectively.

Table 2: Variation analysis of postharvest traits of the rose flower cv. "Avalanche"

Mean Squares						
Source of Variation	**df**	**Vase-life (day)**	**Water absorption (g/3branch)**	**RFW% (2thday)**	**RFW% (4thday)**	**RFW% (5thday)**
Block	2	0.82ns	69.17ns	1.96ns	5.59ns	49.86ns
Treatment	15	0.77*	386.26**	2.60ns	78.05*	149.92*
Error	30	0.26	140.59	1.46	36.36	62.58

**, * and ns: Significant in 0.01, 0.05 and non-significant, respectively.

4.1 Flower diameter

The maximum flower diameter was 36.33 mm obtained from T_3 (200 ppm gibberellic acid) and then 35.50 mm from T_{13} (200 ppm salicylic acid). The lowest flower diameter is 29.00 mm seen in T_8 (100 ppm salicylic acid +300 ppm gibberellic acid) (Table 3). (Rajesh, 2012) reported that with 300 ppm of gibberellic acid, the flower diameter significantly increased in rose flower cv. "Grand Gala". (Jahanbazi *et al.,* 2014) stated that spraying 14 and 21 ppm salicylic acid before harvest increased flower diameter at $P \leq 0.05$ than the control in the rose flower cv. "Angelina". The result of this experiment in increasing the flower diameter due to gibberellic acid and salicylic acid is consistent with the results of other researchers, but in a number of compound treatments (salicylic acid + gibberellic acid), the flower diameter decreased than the control.

4.2 Stem diameter

In this experiment, the maximum stem diameter of 6.08 mm was obtained from T_4 (300 ppm gibberellic acid), then 5.88 mm and 5.85 mm, respectively seen in T_6 (100 ppm salicylic acid + 100 ppm gibberellic acid) and T_3 (200 ppm gibberellic acid). The lowest stem diameter of 5.00 mm was seen in T_1 (control) (Table 3). (Jahanbazi *et al.,* 2014) stated that spraying 7 ppm salicylic acid at pre-harvest of the rose flower cv. "Angelina" increased stem diameter at $P \leq 0.05$ than the control, but in this experiment, the largest diameter was obtained from *gibberellic acid*.

4.3 Flower length

According to the results of comparing the averages, the maximum flower length of the rose flower cv. "Avalanche" 55.90 mm, and 50.53 mm were respectively obtained from T_4 (300 ppm gibberellic acid) and T_9 (150 ppm salicylic acid). The lowest flower length,

46.97 mm, compared to all treatments, was obtained from the compound treatment of T_{16} (200 ppm salicylic acid + 300 ppm gibberellic acid) (Table 3). (Hashemabadi and Zarchini, 2010) reported that using 200 ppm of gibberellic acid before harvest increased the bud length of the rose flower cv. "Poison". (Rajesh, 2012) reported that 300 ppm gibberellic acid significantly increased flower length and stem length in the rose flower cv. "Grand Gala", which is consistence with the results of the present study.

4.4 Stem length

The longest stem length, 74.37 cm, was obtained from T_{16} (200 ppm salicylic acid + 300 ppm gibberellic acid), and the lowest stem length, 60.50 cm, was obtained from T_1 (Table 3). (Rajesh, 2012) found that 300 ppm of gibberellic acid significantly increased stem length in the rose flower cv. "Grand Gala". (Hashemabadi and Zarchini, 2010) reported that pre-harvest using 300 ppm of gibberellic acid increased the stem length of the rose flower cv. "Poison". (Tabizadeh *et al.,* 2015) reported that the spray of 50 and 100 ppm salicylic acid before harvest on the rose flower cv. "Angelina" by increased chlorophyll (A, B, and total), anthocyanins of petals, total nitrogen, potassium, and phosphorus, increased traits such as leaf area, stem length, and the yield on the rose flower cv. "Angelina". The result of this experiment in increasing stem length is similar to the results of the above researchers.

4.5 Number of branches per plant

The highest number of flowers per plant, 6.92 flower branches, was obtained from T_{15} (200 ppm salicylic acid + 200 ppm gibberellic acid). The lowest number of flower branches per plant, 4.42 and 4.67 flowers, respectively, was obtained from T_{11} (150 ppm salicylic acid + 200 ppm gibberellic acid) and T_1 (Table 3). (Hashemabadi and Zarchini, 2010) showed that pre-harvest use of gibberellic acid, salicylic acid, and cycocel significantly increased the number of flower branches in the experimental unit as the concentration of 200 ppm gibberellic acid caused 56.08% performance per square meter per year is higher than the control. (Parmar *et al.,* 2015) found that treatment with 200 ppm of gibberellic acid was the most effective treatment for increasing the number of flowers per plant, the number of flowers per square meter of land, and the number of flowers per hectare in the rose flower cv. "Passion", which increased 15 times higher than control. (Kusumawati *et al.,* 2015) found that a concentration of 200 ppm of gibberellic acid with compost residues on the rose flower cv. "Galica" significantly increased the number of flowers per plant before harvest. (Tabibzadeh *et al.,* 2015) reported that spraying 50 and 100 ppm salicylic acid on the rose flower cv. "Angelina," before harvest, increased the yield. (Jahanbazi *et al.,* 2014) reported that spraying 14 ppm salicylic acid on the rose flower cv. "Angelina" increased the number of flowering branches 5% per plant. The results obtained in this experiment are consistent with the results of the above researchers for the single and compound concentrations of gibberellic acid, and salicylic acid increased product than the control.

Table 3: Comparison mean characteristics in pre-harvest parameters of rose flower cv. "Avalanche"

Treatments (ppm)	Flower diameter (mm)	Stem diameter (mm)	Flower length (mm)	Stem length (cm)	No. Flower per branch
T_1 (SA0+GA0)	30.33^{bcde}	5.00^{d}	50.03^{bcde}	60.50^{e}	4.67^{e}
T_2 (SA0+GA100)	32.33^{bcde}	5.64^{abc}	51.50^{bcd}	65.13^{cde}	5.17^{cde}
T_3 (SA0+GA200)	36.33^{a}	5.85^{abc}	51.50^{bcd}	69.23^{abcd}	5.75^{abcd}
T_4 (SA0+GA300)	33.03^{abc}	6.06^{a}	55.90^{a}	69.87^{abcd}	6.53^{ab}c
T_5 (SA100+GA0)	33.33^{ab}	5.38^{bcd}	52.63^{abc}	61.03^{e}	5.83^{abcd}
T_6 (SA100+100)	31.23^{bcde}	5.88^{ab}	50.53^{bcde}	70.43^{abcd}	6.00^{abc}
T_7 (SA100+GA200)	32.47^{bcde}	5.79^{abc}	51.10^{bcd}	69.70^{abcd}	5.00^{cde}
T_8 (SA100+GA300)	29.00^{e}	5.54^{bc}	49.03^{cde}	73.73^{ab}	5.17^{cde}
T_9 (SA150+GA0)	33.33^{ab}	5.39^{bcd}	53.50^{ab}	65.47^{cde}	5.42^{bcde}
T_{10} (SA150+GA100)	32.00^{bcde}	5.53^{bc}	51.67^{bcd}	66.80^{bcde}	5.17^{cde}
T_{11} (SA150+GA200)	32.33^{bcde}	5.33^{cd}	51.23^{bcd}	71.20^{abc}	4.42^{e}
T_{12} (SA150+GA300)	29.60^{cde}	5.38^{bcd}	47.97^{de}	71.40^{abc}	5.42^{bcde}
T_{13} (SA200+GA0)	33.50^{ab}	5.61^{abc}	53.07^{abc}	63.20^{de}	5.50^{bcde}
T_{14} (SA200+GA100)	32.73^{bcd}	5.46^{bcd}	53.30^{abc}	64.53^{cde}	5.17^{cde}
T_{15} (SA200+GA200)	31.40^{bcde}	5.81^{abc}	49.93^{bcde}	70.70^{abc}	6.92^{a}
T_{16} (SA200+GA300)	29.30^{de}	5.67^{abc}	46.97^{e}	74.37^{a}	5.42^{bcde}

Means within column followed by the same letter are not significantly different at P≤ 0.05 according to the least significant difference (LSD) test.

4.6 Vase-life

Of all treatments, T_5 (100 ppm salicylic acid) was able to significantly increase the vase-life of flowers by absorbing more water for 7 days, and the lowest vase-life of flowers were 5.00, 5.00 and 5.33 days, respectively was obtained from T_2, T_{14} and T_1 treatments (Table 4). In an experiment, (Hashemabadi and Zarchini, 2010) found that concentrations of 100 and 150 ppm of salicylic acid, respectively, were able to increase the vase-life of the rose flower cv. "Poison" by 2 and 3 days compared to the control and also stated that spraying 150 and 250 ppm of gibberellic acid before harvesting was able to increase the vase-life of the rose flower cv. "Poison" without significance. The results of this experiment are consistent with their findings. (Asadi *et al.,* 2014) reported that a concentration of 6 ppm of gibberellic acid with sucrose was able to increase the vase-life of (*Dianthus caryophyilus* var Yellow). (Saifuddin *et al.,* 2009) showed that the concentration of 100 ppm of gibberellic acid with 100 ppm naphthalene acetic acid reduces the aging and wilting of petals in *Bougainvillea spectabilis* Flower storage at low temperatures and increasing the relative humidity of the storeroom will prevent further evaporation and wilting of flowers and will increase the vase-life of cut flowers. (Reid, 1985) stated that temperature directly affects respiration rate and related enzymatic reactions. In fact, increasing the temperature within a physiological temperature range will increase the speed of these reactions. Water travels through the xylem to the upper limbs of the plant if this process is immediately prevented by vascular obstruction due to the presence of microorganisms or by increasing evaporation and transpiration due to high temperature and low humidity in water relations; as a result, the rate of evaporation and transpiration is higher than the rate of water absorption, as the flowers suffer from dehydration which reduces the vase-life of the flower.

4.7 water absorption

T_3, T_5, and T_9 treatments respectively absorbed 99.90, 60.60, and 99.56 gr/3branches of water during the storage period, and the lowest water absorption was observed in T_1 with 67.62 g/3three branches (Table 4). Water stress is the result of vascular obstruction or increased evaporation and transpiration. Proper water relations play an important role in the growth of the petals; improper water relations may prevent the full growth of the petals and reduce the vase-life after harvesting. (Ahmadi and Hassani, 2014) reported that temporary treatment of 40 and 60 ppm of gibberellic acid, with 2 and 3% sucrose, increased the amount of chlorophyll in the leaves and had the highest uptake of the solution in the rose flower cv. "Volut". (Hassani and Alimirzai, 2017) presented that the leaf foliar application of 1.5 mM gibberellic acid after harvesting on the rose flower cv. "Rafat Volut" increased the fresh weight and further absorption of the solution.

4.8 Relative fresh weight

Comparing the means, it was found that the relative fresh weight in all treatments on the second day of stock had an upward trend, so that T_9 (150 ppm salicylic acid) with 109.92% had the highest relative fresh weight and the lowest relative fresh weight with 106.22% was observed in T_1 (control). Of all the treatments, T_5 (100 ppm salicylic acid) was better at maintaining water relation from the beginning to the end of storage and did not have a significant reduction in relative fresh weight (Table 4). (Hashemabadi and Zarchini, 2010) stated that spraying 150 and 250 ppm of gibberellic acid before harvest increased the fresh weight on the rose flower cv. "Poison" respectively up to 4 and 3 grams than the control, also the highest relative fresh weight obtained from 150 ppm salicylic acid. The results of this experiment are consistent with Hashemabadi's report.

Table 4: Comparison mean characteristics in postharvest traits of rose flower cv. "Avalanche"

Treatments (ppm)	Vase-life (day)	Water absorption (g/3branche)	RFW% (2thday)	RFW% (4thday)	RFW% (5thday)
T_1 (SA0+GA0)	5.00^{c}	67.62^{e}	106.22^{d}	87.53^{d}	69.71^{ef}
T_2 (SA0+GA100)	5.00^{c}	71.64c^{de}	107.67^{bcd}	88.32^{cd}	67.90^{f}
T_3 (SA0+GA200)	5.67b^{c}	99.90^{a}	107.95^{abcd}	98.24^{abc}	87.26^{abc}
T_4 (SA0+GA300)	5.67^{bc}	90.01^{abc}	108.97^{abc}	90.61^{bcd}	78.49^{bcdef}
T_5 (SA100+GA0)	7.00^{a}	99.60^{a}	109.67^{ab}	104.82^{a}	92.15^{a}
T_6 (SA100+100)	5.33^{c}	84.64^{abcde}	108.09^{abcd}	87.06^{d}	73.28^{def}
T_7 (SA100+GA200)	6.33^{ab}	83.42^{abcde}	107.15^{cd}	93.52^{bcd}	78.78^{bc}def
T_8 (SA100+GA300)	5.33^{c}	88.42^{abcd}	107.68^{bcd}	86.98^{d}	72.43^{def}
T_9 (SA150+GA0)	5.83^{bc}	9956^{a}	109.92^{a}	96.16^{abcd}	82.08^{abcde}

T_{10} (SA150+GA100)	5.67^{bc}	97.37^{a}	107.97^{abcd}	91.55^{bcd}	81.55^{abcde}
T_{11} (SA150+GA200)	5.67^{bc}	80.93^{abcde}	107.68^{bcd}	93.75^{bcd}	81.11^{abcde}
T_{12} (SA150+GA300)	5.67^{bc}	76.76^{bcde}	108.10^{abcd}	91.53^{bcd}	78.66^{bcdef}
T_{13} (SA200+GA0)	5.67^{bc}	75.33^{bcde}	107.63^{cd}	95.72^{abcd}	91.41^{ab}
T_{14} (SA200+GA100)	5.00^{c}	73.19^{bcde}	109.12^{abc}	88.50^{cd}	75.26^{cdef}
T_{15} (SA200+GA200)	5.67^{bc}	92.44^{ab}	108.26^{abc}	100.16^{ab}	83.33^{abcd}
T_{16} (SA200+GA300)	5.33^{c}	69.37^{de}	107.72^{bcd}	93.33^{bcd}	84.20^{abcd}

Means within column followed by the same letter are not significantly different at P≤ 0.05 according to the least significant difference (LSD) test.

5. Conclusion

The purpose of this experiment is to investigate the effects of gibberellic acid and salicylic acid on the quality, quantity, and vase-life of the rose flower cv. "Avalanche". The results of this experiment showed that the spray of growth regulators in different concentrations can increase traits like flower diameter, stem diameter, flower length, stem length, and the number of flowers per plant, and through further absorption of the solution, it can significantly increase vase-life of rose than the control (water spray). In addition, single treatments compared to compound treatments (salicylic acid + gibberellic acid) were more effective in increasing the quality, quantity, and vase-life of the rose flower cv. "Avalanche". Because the Avalanche variety of roses has small flowers, less height, and less vase- life, therefore the effects of these hormones in increasing the quality, quantity, and life of roses after harvesting are very important. Respected to other researchers in the floriculture area can investigate the effect of the application of these hormones on the physiological characteristics of roses (amount of chlorophyll, anthocyanin, and flower nectar).

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