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Influence of pre-harvest sprays on flower quality and vase life of *Alstroemeria*

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Abstract
Alstroemeria, commonly known as Peruvian Lily, has high demand in the global market. The flowers are popularly known for their wide range of colours. Short postharvest life is a significant problem in *Alstroemeria* flowers. The objective of the study is to extend the vase life of flowers by application of pre-harvest foliar sprays. Foliar spray of Salicylic acid (50, 100 & 150 µM), Benzyl Adenine (50, 100 & 150 µM) and Gibberellic acid (200, 250 & 300 ppm) were applied twice during 2 weeks and 1 week before flower harvest with distilled water as control. The harvested flowers were placed in conical flasks containing distilled water as vase solution, and parameters like relative fresh weight, vase solution uptake, floret diameter, total chlorophyll content, ethylene evolution and vase life were recorded. The results showed that pre-harvest treatment of flowers with Gibberellic acid @ 300 ppm showed a significant increase in floret diameter (7.6 cm), total chlorophyll content (0.72 mg g^{-1} of fresh leaf), high relative fresh weight (88.50%) and high uptake of vase solution (2 g $stem^{-1}$ day^{-1}). Treatment with Benzyl adenine @ 150 µM has given favourable result by increasing the vase life of the flower up to 8 days followed by Gibberellic acid @ 300 ppm (7 days). Treatment with Salicylic acid did not show any favourable result. There was no significant difference in ethylene evolution pattern among treatments. From this experiment, it is concluded that pre-harvest treatment of flowers with Gibberellic acid @ 300 ppm and treatment of flowers with Benzyl adenine @ 150 µM showed positive results with treatment using Gibberellic acid @ 300 ppm as the best treatment.

Keywords: *Alstroemeria*, pre-harvest spray, gibberellic acid, benzyl adenine, salicylic acid

Introduction
Alstroemeria, commonly known as Peruvian Lily or Lily of the Incas, belongs to the family Alstroemeriaceae. It is an important cut flower popularly known for its vast and vibrant colour range. It has a high demand in the local and global flower market (Yeat *et al*., 2012) [1]. *Alstroemeria* is a native of South America.

Improvement of vase life and maintaining the flower quality are essential quality attributes in economically important cut flowers. Senescence of cut flowers depends on various factors like; water stress (Sankat and Mujaffar, 1993) [2], carbohydrate depletion, microorganisms (Witte and van Doorn, 1991) [3] and ethylene effects (Wu *et al*., 1991) [4].

Short postharvest vase life reduces the market potential of *Alstroemeria* flowers. Leaf yellowing associated with early senescence is a major problem in *Alstroemeria*, which may occur within a few days and proceeds very rapidly. In *Alstroemeria*, leaf yellowing preceeds senescence of the secondary florets (Mutui *et al*., 2001) [5]. The critical quality attribute of *Alstroemeria* is retaining leaf greenness (Mutui *et al*., 2006) [6]. The postharvest life of *Alstroemeria* floral organs is typically long and is terminated by petal abscission. However, in many cultivars, yellowing of the leaves on cut stems occurs within a few days and proceeds very rapidly (Ferrante *et al*., 2002) [7].

The growth conditions of the plant before harvest would affect the quality of the cut flowers by about 30 - 70% (Halevy and Mayak, 1981) [8]. It has been reported that pre-harvest spray of Salicylic acid has shown a significant difference in morphological, physical parameters and vase life in the flowers like; Lilium (Hajizadeh and Aliloo, 2013) [9], Cut Rose (Kazemi *et al*., 2018) [10] and *Alstroemeria* (Ershad Langroudi *et al*., 2020) [11]. The use of Gibberellic acid and Benzyl Adenine as pre-harvest sprays has shown promising results in improving the flower quality (Sajid *et al*., 2018) [12], chlorophyll content and vase life (Abshahi *et al*., 2014) [13].

Therefore, the objective of this research is to study the effect of pre-harvest foliar sprays on keeping quality and vase life of *Alstroemeria* flowers.

Materials and Methods
The experiment was conducted during 2019-2020 at Woodhouse farm, Horticultural Research Station, Tamil Nadu Agricultural University, The Nilgiris which is located 11.4025'N Latitude

and 76.735'E Longitude and at an altitude of about 2653 m above Mean Sea Level. The experiment was carried out in Randomized block design with 10 treatments and three replications with nine plants per replication. *Alstroemeria hybrida* cv. Pink Panther was selected for the experiment due to its market preference. Pre-harvest foliar sprays of treatments with different concentrations of Salicylic acid (50, 100 & 150 µM), Benzyl Adenine (50, 100 & 150 µM) and Gibberellic acid (200, 250 & 300 ppm) were applied twice at two weeks and one week before flower harvest with distilled water as control. The flowers were harvested when florets were in bud stage when the primary florets show colour and are about to open. The harvested flower stems were pre-cooled, graded and packed in polyethene covers before being transported to the laboratory at Tamil Nadu Agricultural University, Coimbatore. The flower stems were cut underwater to approximately 45cm length and placed in conical flasks containing 100 ml distilled water.

Relative fresh weight and Vase solution uptake

Relative fresh weight and vase solution uptake were measured in the interval of two days by recording the fresh weight of the flower stems and vase solution weight till the end of vase life. Relative fresh weight and vase solution uptake were calculated using the formula given by (He *et al*., 2006) [14]. Relative fresh weight was calculated as $RFW\,(\%) = (W_t / W_{t=0}) \times 100$; where, W_t indicates weight of the flower stem (g) on t = day 2, 4, 6, etc., and $W_{t=0}$ indicates weight of the flower stem (g) on t = day 0. The vase solution uptake was calculated using the formula $\text{Vase solution uptake}\ (g\ stem^{-1}\ day^{-1}) = (S_{t-1} - S_t)$; where S_t indicates vase solution weight (g) on t = day 2, 4, 6, etc., and S_{t-1} indicates vase solution weight (g) on the previous day.

Floret diameter

Floret diameter of the individual florets was measured horizontally across the petal's ends after the florets are completely open, and the mean value was calculated. Floret diameter is expressed in centimetre (cm).

Vase life

The vase life of the flowers was assessed visually as days taken for wilting of 50% florets, and 50% leaves turn yellow when the flowers become less attractive.

Total Chlorophyll content

Total chlorophyll content was assessed using 80% Acetone as per the method suggested by (Sadasivam and Manickam, 1992) [15]. 250 mg of leaf sample was weighed and macerated using 10 ml of 80% Acetone. The contents were centrifuged at 3000 rpm for 10 minutes. The supernatants were collected, and their optical density at 645 and 663 nm were measured respectively using UV-1800 Shimadzu spectrophotometer.

$$\text{Total Chlorophyll (mg/ g)} = (8.02 \times OD\ @\ 663\ nm) + (20.2 \times OD\ @\ 645\ nm) \times \frac{V}{1000 \times W}$$

Ethylene evolution

Ethylene production from flowers was measured using F-950 Three Gas Analyzer by Felix instruments, a handheld portable Ethylene Analyzer. F-950 uses an electrochemical cell to measure ethylene. The sampling probes were connected to the intake of F-950, and 1µM PTFE hydrophobic needle filter was connected to the tube end to prevent the entry of moisture or debris into the instrument. A sterile needle was attached to the filter. The flower stems were packed in polythene bags and sealed. Ethylene production was measured regularly by directly injecting the sterile needle into the package. Ethylene evolution was expressed in parts per million (ppm).

The datas were analysed as per the standard procedures suggested by (Panse and Sukhatme, 1978).

Results and Discussion

Relative fresh weight and vase solution uptake

The data for the effect of different pre-harvest foliar sprays on relative fresh weight and vase solution uptake are as furnished in Table-1. As shown in the data, there has been a significant increase in relative fresh weight of the flowers in the first four days. This result is similar to the pattern recorded by (Ershad Langroudi *et al*., 2020) [11] in *Alstroemeria* and (Alaey *et al*., 2011) [17] in Cut Roses. The increase in relative fresh weight may be due to the uptake of the vase solution by the flowers. After forth day, the relative fresh weight decreased significantly till the end of vase life of the flower. This decrease in relative fresh weight may be due to decrease in water uptake of the flowers (Alaey *et al*., 2011) [17]. A significant variation was observed among the treatments. This shows that relative fresh weight was significantly affected by pre-harvest foliar spray with GA_3 @ 300 ppm which resulted in highest relative fresh weight (88.50%) followed by Benzyl Adenine @ 150 µM (87.18%), while the control showed lowest relative fresh weight (51.19%).

Table 1: Effect of different treatments on relative fresh weight and vase solution uptake of *Alstroemeria* flowers

Treatments	Relative fresh weight (%)				Vase solution uptake (g/ stem/ day)			
	Day 2	Day 4	Day 6	Day 8	Day 2	Day 4	Day 6	Day 8
SA @ 50 µM	103.94	103.94	92.13	82.41	4.00	3.00	1.33	0.33
SA @ 100 µM	104.76	107.54	75.79	56.35	3.33	1.17	1.08	0.67
SA @ 150 µM	117.26	113.10	91.56	63.66	2.67	2.00	1.50	0.33
BA @ 50 µM	101.75	97.44	80.16	62.89	4.33	3.00	2.00	0.67
BA @ 100 µM	102.08	100.00	86.81	73.15	3.67	2.33	2.17	1.00
BA @ 150 µM	105.75	104.31	96.47	87.18	4.33	3.33	2.42	1.67
GA_3 @ 200 ppm	107.36	103.53	95.76	81.15	4.33	3.67	2.25	1.67
GA_3 @ 250 ppm	107.37	102.67	93.28	80.70	2.33	2.33	1.83	0.33
GA_3 @ 300 ppm	106.00	105.41	97.63	88.50	4.67	3.33	2.92	2.00
Control	101.90	86.16	66.27	51.19	4.33	3.00	0.58	0.17
S. Ed	4.27	3.30	4.95	5.81	0.60	0.38	0.18	0.33
CD (0.05)	8.98	6.94	10.40	12.20	1.26	0.80	0.38	0.69
	NS	S	S	S	NS	S	S	S

The results showed that there is a significant difference in uptake of vase solution among treatments. The highest vase solution uptake on the eighth day was recorded in the flowers treated with GA_3 @ 300 ppm (2 g stem^{-1} day^{-1}) while the control flowers showed lowest vase solution uptake (0.17 g stem^{-1} day^{-1}). This indicates that pre-harvest treatment with Gibberellic acid @ 300 ppm improves uptake of vase solution, thereby increasing the keeping quality and vase life of flowers.

Floret diameter, Total Chlorophyll content and Vase life

The data obtained for the effect of different pre-harvest foliar sprays on floret diameter, total chlorophyll content and vase life of *Alstroemeria* flowers are provided in Table 2. The treatments showed a significant difference for floret diameter, vase life of the flower and total chlorophyll content. Among the treatments, the flowers treated with GA_3 @ 300 ppm showed more effective in increasing the floret diameter with the highest diameter (7.92 cm). A similar effect of GA_3 on floret diameter was observed by (Yeat *et al*., 2012) [1] in *Alstroemeria* and (Kapri *et al*., 2018) [18] in Lily. The lowest floret diameter (6.08 cm) was reported in control flowers. This positive effect of gibberellins on floret diameter might be due to induction of cell division and increased rate of accumulates resulted from better physiological efficiency, selective ion uptake and adequate water uptake (Rani and Singh, 2013) [19].

Table 2: Effect of different treatments on floret diameter, vase life and total chlorophyll content of *Alstroemeria* flowers

Treatments	Floret Diameter (cm)	Vase life (days)	Total Chlorophyll content (mg/ g)			
			Day 2	Day 4	Day 6	Day 8
SA @ 50µM	6.33	4.67	0.57	0.43	0.32	0.22
SA @ 100µM	6.20	4.33	0.59	0.43	0.33	0.21
SA @ 150µM	6.13	5.00	0.61	0.46	0.37	0.24
BA @ 50µM	6.50	5.67	0.71	0.63	0.47	0.33
BA @ 100µM	6.14	6.67	0.75	0.68	0.51	0.35
BA @ 150µM	6.67	7.67	0.85	0.76	0.58	0.44
GA_3 @ 200ppm	7.58	7.00	0.79	0.65	0.49	0.33
GA_3 @ 250ppm	6.83	5.33	0.81	0.72	0.52	0.36
GA_3 @ 300ppm	7.92	7.33	1.04	0.76	0.60	0.48
Control	6.08	3.33	0.73	0.43	0.22	0.17
S. Ed	0.13	0.34	0.02	0.01	0.00	0.01
CD (0.05)	0.28	0.71	0.04	0.03	0.00	0.03
	S	S	S	S	S	S

The flowers treated with Benzyl Adenine showed a significant difference in increasing the vase life of *Alstroemeria* flowers. The highest vase life (8 days) was reported in Benzyl Adenine @ 150 µM while the lowest vase life was reported in control flowers (3 days). Treatment of *Alstroemeria* flowers with BA @ 150 µM has significantly increased the vase life of flowers by five days, more remarkable than control flowers. This is similar to the results achieved by (Kapri *et al*., 2018) [18] in lily. The application of Benzyl Adenine helps extend the vase life of flowers by reducing the abscission process. The enhancement of vase life by exogenous application of cytokinins results from a decrease in the rate of respiration that leads to delayed flower senescence. Benzyl Adenine also leads to improved cell membrane permanency, delayed lipid peroxidation and decrease in leakage of ions resulting in increased vase life of cut flowers (Emami *et al*., 2011) [20].

The result showed a significant difference in the total chlorophyll content in the flower stem leaves among treatments. The total chlorophyll content decreases throughout the vase life in all treatments. However, the highest total chlorophyll content among the treatments on the eighth day was observed in Gibberellic acid @ 300 ppm (0.48 mg g^{-1}) while the control reported lowest total chlorophyll content (0.17 mg g^{-1}). Treatment of flowers with Benzyl Adenine @ 150 µM has also shown a positive result in maintaining the total chlorophyll content. The results are in association with studies by (Yeat *et al*., 2012) [1] and (Mutui *et al*., 2001) [5]. The reduction in photosynthesis under certain threshold level might induce a signal for inducing senescence of leaves (Smart, 1994) [21]. However, treatment with Gibberellic acid delays the decline in the rate of photosynthesis and reduces leaf senescence and chlorophyll degradation (Yeat *et al*., 2012) [1].

Ethylene evolution

Ethylene evolution from the whole flower stem in each treatment was evaluated and presented in Table 3. From the observations, it can be noticed that in few flower stems leaf senescence had occurred earlier even when the ethylene evolution was low and did not attain the maximum level. Hence, it can be interpreted that senescence of leaf is independent of the ethylene production rate. A similar report was made by (Wagstaff *et al*., 2005) [22] on evaluating the association of petal senescence, ethylene production and flower longevity in *Alstroemeria* flowers. The study concluded that the flowers are sensitive to minimal ethylene concentrations and sensitivity develops in the later stage of the vase life.

From the data recorded, it can be observed that among the treatments, the ethylene level reached its maximum level earlier on the fifth day in control flowers. While the maximum ethylene production was recorded at the seventh and eighth day in Gibberellic acid and Benzyl Adenine treated flowers (Fig. 1). Since the flower senescence was less sensitive to endogenous ethylene production, evaluation of the flower stems was done visually and the flowers treated with Gibberellic acid @ 300 ppm and Benzyl Adenine @ 150µM was reported to show better performance.

Table 3: Effect of various treatments on ethylene production (in ppm) of *Alstroemeria* flowers

Treatments	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		Day 8	
	9:00 AM	9:00 PM	9:00 AM	9:00 PM	9:00 AM	9:00 PM	9:00 AM	9:00 PM	9:00 AM	9:00 PM	9:00 AM	9:00 PM	9:00 AM	9:00 PM	9:00 AM	9:00 PM
SA @ 50µM	0.1	0.4	0.1	0.4	0.3	0.4	0.4	0.3	0.9	0.5	1.9	0.7	3.4	1.3	2.7	0.8
SA @ 100µM	0.1	0.5	0.1	0.5	0.4	0.5	0.6	0.4	1.0	0.6	1.7	0.9	2.9	1.5	2.5	0.7
SA @ 150µM	0.1	0.5	0.2	0.5	0.3	0.5	0.4	0.3	1.2	0.5	2.0	1.0	4.2	1.2	2.9	0.8
BA @ 50µM	0.1	0.6	0.3	0.5	0.3	0.6	0.5	0.3	0.7	0.3	1.9	0.8	3.1	1.5	2.3	0.3
BA @ 100µM	0.1	0.5	0.2	0.4	0.2	0.4	0.6	0.4	0.5	0.4	1.1	0.4	3.6	2	2.9	0.7
BA @ 150µM	0.1	0.5	0.2	0.5	0.4	0.6	0.8	0.5	0.3	0.0	0.8	0.5	1.0	0.4	2.6	0.6
GA_3 @ 200ppm	0.1	0.4	0.1	0.3	0.3	0.5	0.6	0.4	0.3	0.4	0.8	0.5	3.3	0.5	1.9	0.8
GA_3 @ 250ppm	0.1	0.5	0.1	0.4	0.3	0.5	0.7	0.5	0.4	0.3	0.9	0.4	3.5	1.7	1.7	0.9
GA_3 @ 300ppm	0.1	0.5	0.0	0.4	0.4	0.5	0.7	0.5	0.3	0.2	0.7	0.4	1.2	0.7	3.0	0.8
Control	0.1	0.7	0.1	0.5	0.3	0.6	1.1	0.3	3.4	1.7	1.6	0.5	0.7	0.4	0.4	0.4

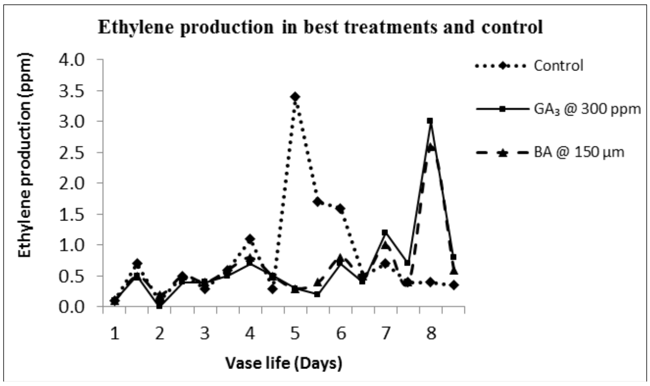

Fig 1: Ethylene evolution in control flowers, flowers treated with GA_3 @ 300 ppm and BA @ 150 µM

Conclusion

The results of the experiment show that pre-harvest foliar application of Gibberellic acid @ 300 ppm twice during two weeks and one week before flower harvest helps in improving floret diameter, relative water content, water uptake and total chlorophyll content of *Alstroemeria* flowers. Whereas, application of Benzyl Adenine @ 150 µM increased the postharvest life of the flower. Among these chemicals, Gibberellic acid is readily available in commercial form and is comparatively less expensive. Hence, the use of Gibberellic acid would be more beneficial in improving the floral attributes and vase life of *Alstroemeria* flowers.

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