

Effect of postharvest treatments on the longevity of cut inflorescences of 'Rialto' oriental lily

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ABSTRACT

Cut lily flowers are very popular but their longevity is not satisfactory. The quality of cut lily flowers is determined by two factors: the longevity of the flowers and the general appearance of the entire cut stem during its vase life. The aim of this work was to evaluate the effects of gibberellic acid (GA_3), standard preservative (8HQC and 2% sucrose) and commercial preservatives Chrysal Professional 2 and Chrysal sachet as well as Floralife 200 and Floralife 300 on the quality of 'Rialto' cut oriental lily, a white blooming cultivar very popular on the Polish market. The contents of reducing sugars, soluble proteins, free amino acids and free proline were also determined in the senescing flowers. As a major problem in the postharvest handling of lilies is leaf yellowing, the effects of postharvest treatments on the quality of leaves and their chlorophyll contents were also studied. Conditioning (24 h) with GA_3 (500 mg d.m.⁻³) immediately after harvest delayed chlorophyll loss in leaves. When combined with the standard preservative and commercial preparations Chrysal Professional 2 and Chrysal sachet as well as Floralife 200 and Floralife 300, GA_3 prolonged flower vase life. The most effective method was using GA_3 and Floralife products, which prolonged the vase life of flowers to 23 days, 43% longer relative to the untreated flowers, and maintained the decorative value of the leaves (53 days). During the senescence of flowers held in water, the contents of reducing sugars, free amino acids and proline increased. However, the holding solutions modified changes in these parameters relative to the control.

Key words: chlorophyll, free proline, gibberellic acid, preservative, senescence, soluble proteins, vase life

Abbreviations:

8HQC – 8-hydroxyquinoline citrate; GA_3 – gibberellic acid; S – sucrose; SP – standard preservative

INTRODUCTION

Lilies are one of the most important bulbous plants grown for cut flowers (van Doorn and Han 2011). As their flowering can be controlled, cut lilies are available on the market all year long. Until recently, Asiatic lilies were dominating but due to a lower profitability they have been replaced by Oriental

lilies and LA lilies, i.e. hybrids of *Lilium longiflorum* and Asiatic lilies (Grassotti and Gimelli 2011).

The postharvest longevity of lilies depends on the cultivar, growing conditions and conditions during storage and transport. The first visible sign of senescence in lilies is leaf yellowing and browning, which considerably lowers the decorative values of cut inflorescences (Han 1997, 2001). Chlorosis

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begins in the lower stem part and proceeds upwards towards the flowers. Some buds stop developing and dry out, which further lowers the quality of the entire inflorescence (van Doorn and Han 2011).

Exogenous sugar applied with a biocide as a flower preservative significantly prolongs the longevity of cut flowers and improves their development and colouring (Song et al. 1996). The supplementation of sucrose delays proteolysis in petals and limits the accumulation of free amino acids and pH increases in cell sap (Gao and Wu 1990), which results in a delay in flower senescence most likely due to increasing the endogenous sugar pool in petals. However, sugar may also negatively affect the postharvest quality by decreasing foliage longevity. The presence of 2% sucrose in a vase solution hastened foliage chlorosis of lily in comparison to flowers held in a solution without sucrose (Han 2003).

The higher sucrose concentration (5%) proved phytotoxic, causing leaf blackening, which might have resulted from excessive sugar accumulation in leaf tissues and their desiccation due to water withdrawal from cells (Han 2003). The results of experiments on 'Helvetia' (Rabiza-Świder et al. 2012) and 'Richmond' (Rabiza-Świder et al. 2015) lilies, as well as earlier reports by Han (2003) and van Doorn (2008) concerning several lily cultivars, prove that sucrose used in different concentrations negatively affects leaf quality in lilies.

Generally, a negative sugar effect may be mitigated by the application of growth regulators such as cytokinins and gibberellins (Han 2003). They both delay foliage senescence in many cut flowers (van Doorn et al. 1992), including lilies (Han 1997). In 'Helvetia' Oriental lily, GA₃ in a concentration of 500 mg d.m.⁻³ increased leaf longevity 1.3 times as compared to untreated leaves. This effect was increased by the joint application of GA₃ and the cytokinin benzyladenine; leaves of lilies conditioned in BA and held in GA₃ solution (both in the same concentration of 500 mg d.m.⁻³) lasted 27 days, i.e. 10 days longer than control untreated leaves and four days longer than those kept in GA₃ without previous conditioning (Rabiza-Świder et al. 2012). These results are in line with those of other scientists, described by van Doorn (2010). It is worth noting that BA alone decreased leaf longevity in LO 'Helvetia'. According to Han (2000), the application of gibberellin to lily foliage is more efficient than treatment with benzyladenine.

Several lily cultivars from the three main groups were screened for their response to ethylene. The vase

life of most Oriental hybrid and *Lilium longiflorum* cultivars is unaffected by ethylene exposure. Some Asiatic hybrids show minor responses, as noted Elgar et al. (1999) for the cultivars 'Apeldoorn', 'Goldena', 'Elite' and 'Mona'. Endogenous ethylene production by all lily cultivars is close to or below the limits of detection (Elgar et al. 1999). Han and Miller (2003) indicate that freshly harvested 'Stargazer' were not sensitive to ethylene. The sensitivity of 'Stargazer' to ethylene, however, increased dramatically following cold storage, as exposure of cold-stored stems to ethylene concentrations as low as 0.3 µl d.m.⁻³ significantly affected bud opening. In a comprehensive investigation looking at the sensitivity of flowers to ethylene, Woltering and van Doorn (1988) categorized the responses of lily flowers to ethylene as insensitive to low sensitivity.

Commercial preservatives for cut flowers have been developed for every stage of flower turnover. They are used to assure the best quality of cut plant material during the entire market chain, including long storage and long distance transport. The best known companies producing such preservatives are Chrysal International BV and Floralife Inc. (a division of Smithers-Oasis Company).

While using Chrysal products, the series Chrysal Professional should be applied after conditioning while in the case of Floralife, it is the series Floralife 200. These products lower the pH of a vase solution, improve water conductance, provide a minimum amount of nutritive compounds and delay premature bud opening and peduncle bending. During the last phase of turnover, flower longevity may be prolonged by using 'flower food'. These preservatives are often available as easy-to-use sachets. They contain nutrients enabling full bud opening and biocides controlling bacterial growth in the vase (holding solution). For individual customers, Chrysal recommends Chrysal Clear, while its analogue produced by Floralife is Floralife 300.

The aim of this study was to analyse certain senescence-related processes such as the degradation of proteins, accumulation of free amino acids and free proline and changes in sugar content in cut 'Rialto' lilies in order to elaborate methods for the proper handling of lilies during harvest, storage and transport, ensuring their best postharvest quality.

MATERIAL AND METHODS

'Rialto' oriental lilies grown in a greenhouse were cut in July when the first bud in an inflorescence

was fully developed and coloured but yet unopened. Two flower buds were left on each shoot. Stems were recut to 50 cm and placed into beakers filled with distilled water or gibberellic acid after the basal leaves had been removed from the stems. Gibberellic acid (GA_3) was applied in a concentration of 500 mg d.m.⁻³ as a 24 h pulse treatment, after which stems were transferred to distilled water, a standard preservative (SP) solution composed of 200 mg d.m.⁻³ 8HQC and 2% sucrose (S) or commercial preparations recommended by Chrysal (Chrysal Professional 2) and Floralife (Floralife 200) for cut flowers. Both preparations contain biocides, the contents of reducing sugars, soluble proteins, free amino acids and free proline. After three days in Chrysal Professional 2 or Floralife 200, the flowers were transferred to distilled water or water with commercial preservatives: Chrysal sachet or Floralife 300, respectively. Just as SP, Chrysal sachets and Floralife 300 combine biocides and sugar. Stems placed into distilled water served as the control. Neither the preservative nor the water were exchanged during the experiment – they were replenished if needed. The experiment was carried out in a room with a controlled temperature of 20°C ± 1°C, relative humidity of 60% and quantum irradiance of 35 μmol m⁻² s⁻¹, under the 12 h day and 12 h night regime.

Each treatment contained 18 stems, individually tagged and treated as single replicates. The longevity of individual flowers in an inflorescence was assessed according to their appearance as the number of days since bud opening till the appearance of deformations due to tepal withering. The longevity of the inflorescences was assessed as the number of days from the beginning of the experiment until the fading of the second flower. The end of vase life was marked by flower wilting, tepal abscission and/or tepal colour changes while in the case of leaves, by colour fading of the blade, yellowing or drying on 30% of the leaf surface.

During the experiment the plant material was sampled for analyses. Flower samples were collected on day 0 (immediately after cutting off) and on the eighth day after harvest. For chlorophyll analyses, leaf samples were also collected on the 22nd day after harvest. Reducing sugars, total soluble proteins, free amino acids and free proline were determined in the first flower while the contents of chlorophyll *a* + *b* were measured in the leaves.

Material from 10 leaves located in the central part of the stems and four flowers was pooled on each sampling date. For each compound analysed,

three extracts were prepared for each treatment on each sampling date. The results were calculated on a dry matter basis. The dry weight of the petals and leaves was obtained after drying samples at 105°C according to Strzelecka et al. (1982). Chlorophyll was determined after extraction with dimethylformamide (DMF) according to Moran and Porath (1980) as modified by Inskip and Bloom (1985). Reducing sugars were measured by the Somogyi method as modified by Nelson (1944). Soluble proteins were determined according to Bradford (1976), free amino acids by Rosen's method (1957) and free proline according to Bates et al. (1973).

The results were statistically evaluated by ANOVA 1 or ANOVA 2 using the StatGraphics Plus program. Duncan's test at $p = 0.05$ was applied to assess the significant differences between the means.

RESULTS

Postharvest treatments significantly affected the vase life of cut lilies. The effects of gibberellic acid and some preservatives on the longevity of individual lily flowers, of the entire inflorescence and that of the foliage are compared in Table 1. The longevity of flowers standing in water was not affected by the flower age: the first and second flower in an inflorescence had a similar vase life. Conditioning with GA_3 prolonged it in both flowers as well the total vase life of the inflorescence. All of the treatments with GA_3 increased flower longevity relative to control inflorescences placed in water or those transferred into the preservative solutions after 24 h in water. The longest lasting flowers were conditioned 24 h in GA_3 and subsequently placed into the standard preservative 8HQC + 2% S; they lasted 1.6 times longer or almost twice as long as lilies held in water for the entire inflorescence (16 days vs. 25 days) or both individual flower buds (10 days vs. 18 days), respectively.

The use of commercial preparations (Chrysal or Floralife) after conditioning gave better results than placing flowering stems in water and this beneficial effect was especially evident in the total inflorescence longevity. The application of the Floralife preparations (Floralife 200 and Floralife 300) delayed leaf yellowing, regardless of the use of GA_3 . Foliage longevity on stems in both preparations was almost threefold of that on stems held in water. However, due to conditioning with GA_3 followed by using both Floralife preparations, the flower longevity was only 10-14% shorter than

Table 1. The effect of postharvest treatments on the vase life of flowers and postharvest longevity of leaves in 'Rialto' cut oriental lily

Treatment			Vase life of cut flowers [days]			Leaf longevity
			first bud	second bud	inflorescence	
H ₂ O (control)			9.7 a*	9.7 a	16.0 a	19.3 b
H ₂ O cond. 24 h	Chrysal Professional 2 (3 days)	H ₂ O	10.2 ab	10.3 a	16.3 a	14.3 a
	Chrysal Professional 2 (3 days)	Chrysal sachet	10.9 b	11.2 b	18.1 bc	16.2 a
	Floralife 200 (3 days)	H ₂ O	10.1 ab	10.1 a	17.2 ab	20.7 b
	Floralife 200 (3 days)	Floralife 300	10.9 b	11.6 b	18.6 bc	55.2 g
GA ₃ 500 mg d.m. ⁻³ cond. 24 h	H ₂ O		13.2 c	13.7 cd	20.7 e	48.3 f
	8HQC+2% S		18.2 g	17.6 f	25.4 g	32.2 c
	Chrysal Professional 2 (3 days)	H ₂ O	12.4 c	13.0 c	19.1 cd	47.1 f
	Chrysal Professional 2 (3 days)	Chrysal sachet	13.0 c	13.4 cd	20.8 e	36.6 d
	Floralife 200 (3 days)	H ₂ O	14.2 d	14.3 d	20.4 de	43.0 e
	Floralife 200 (3 days)	Floralife 300	15.7 e	15.8 e	22.9 f	52.9 g

*Values in columns marked with the same letter do not differ significantly at $p = 0.05$

Table 2. The effect of postharvest treatments on chlorophyll *a* + *b* content [mg g⁻¹ d.w.] in the leaves of 'Rialto' cut oriental lily; initial chlorophyll content: 19.1 mg g⁻¹ d.w.

Treatment			Chlorophyll <i>a</i> + <i>b</i> content		Mean
			8 day	22 day	
H ₂ O (control)			14.4 c*	4.3 a	12.6 a
H ₂ O cond. 24 h	Chrysal Professional 2 (3 days)	H ₂ O	14.4 c	5.7 b	13.1 a
	Chrysal Professional 2 (3 days)	Chrysal sachet	14.6 c	3.6 a	12.4 a
	Floralife 200 (3 days)	H ₂ O	21.6 k	5.7 b	15.5 ab
	Floralife 200 (3 days)	Floralife 300	20.8 jk	17.1 de	19.0 c
GA ₃ 500 mg d.m. ⁻³ cond. 24 h	H ₂ O		21.0 jk	21.6 k	20.5 c
	8HQC+2%S		21.0 jk	16.6 d	18.9 c
	Chrysal Professional 2 (3 days)	H ₂ O	18.4 fg	20.4 ij	19.3 c
	Chrysal Professional 2 (3 days)	Chrysal sachet	18.0 ef	16.8 d	17.8 bc
	Floralife 200 (3 days)	H ₂ O	20.8 jk	20.1 ij	20.0 c
	Floralife 200 (3 days)	Floralife 300	20.8 jk	19.6 hi	19.8 c
Mean			18.7 b	13.8 a	

*Explanations: see Table 1

in the best combination of treatments (GA₃ 24 h followed by SP) and 1.5 higher than in the control stems held in water.

It should be noted that the most effective combination of treatments for flower longevity (GA₃ 24 h followed by SP) was not the best for the foliage and in this treatment leaf longevity was the shortest among all of the treatments including GA₃.

The application of gibberellic acid increased leaf longevity in all of the cases. The chlorophyll *a* + *b* content in leaves sampled from stems conditioned with GA₃ was higher relative to the unconditioned control (Tab. 2). On the last sampling date (22nd day after harvest), the highest pigment level was found in leaves from stems conditioned in GA₃

and transferred to water; it was five times higher than that determined in the untreated leaves of the control (Tab. 2). Surprisingly high chlorophyll contents were measured in leaves from stems not conditioned with GA₃ and placed into the Floralife preparations: on the 22nd day after harvest the pigment level was four fold of that in the control leaves, being comparable to some treatments involving GA₃.

The statistical analysis proved that the postharvest treatments significantly increased the reducing sugar contents relative to the control flowers and the initial sugar level (Tab. 3). The highest sugar level was found in lilies conditioned with GA₃ and transferred to the standard preservative; it was nine

Table 3. The effect of postharvest treatments on reducing sugars [mg g⁻¹ d.w.], soluble protein content [mg g⁻¹ d.w.], free amino acids [mmol g⁻¹ d.w.] and free proline content [μmol g⁻¹ d.w.] in flowers of ‘Rialto’ cut oriental lily (8 days after harvest)

Treatment			Reducing sugars	Soluble protein	Free amino acids	Free proline
Initial content in freshly harvested flowers			58.8 a*	5.7 a	348.8 ab	3.4 a
H ₂ O (control)			131.5 b	9.3 bc	1255.6 i	7.1 f
H ₂ O cond. 24 h	Chrysal Professional 2 (3 days)	H ₂ O	360.4 d	10.9 cd	786.8 g	5.4 bc
	Chrysal Professional 2 (3 days)	Chrysal sachet	449.0 f	10.0 bcd	1137.6 h	6.7 f
	Floralife 200 (3 days)	H ₂ O	374.6 de	9.4 bc	457.3 cd	6.0 de
	Floralife 200 (3 days)	Floralife 300	405.0 e	7.7 ab	559.7 e	5.2 bc
GA ₃ 500 mg d.m. ⁻³ cond. 24 h	H ₂ O		215.2 c	6.4 a	675.4 f	7.1 f
	8HQC+2%S		530.7 g	11.1 cd	331.4 a	3.7 a
	Chrysal Professional 2 (3 days)	H ₂ O	238.9 c	10.6 cd	759.9 g	6.5 ef
	Chrysal Professional 2 (3 days)	Chrysal sachet	214.3 c	17.7 e	526.0 de	5.1 bc
	Floralife 200 (3 days)	H ₂ O	357.7 d	11.0 cd	526.1 de	5.8 cd
	Floralife 200 (3 days)	Floralife 300	438.0 f	12.6 d	413.4 bc	4.8 b

*Explanations: see Table 1

times higher than immediately after harvest and four times higher than in the control flowers held in water. High sugar contents were also determined in the petals of lilies conditioned in GA₃ and transferred into the Floralife preparations or in flowers kept 24 h in water and subsequently placed into Chrysal Professional 2 or Chrysal sachet. The above treatments increased sugar amounts threefold relative to the water control.

The soluble protein contents are comparable in most treatments (Tab. 3). Only in lilies conditioned with GA₃ and placed into the Chrysal preparations was the protein content significantly higher as compared to other treatments, being twofold of that determined in the control. The lowest soluble protein level was observed immediately after harvest and in flowers conditioned in GA₃ and held in water as well as in flowers placed into water for 24 h and then transferred into the Floralife preparations.

In flowers subjected to postharvest treatments, the levels of free amino acids in lily tepals were lower when compared to the control flowers placed in water immediately after harvest, where it increased 3.5-fold during lily vase life (Tab. 3). The smallest amount of free amino acids was found in flowers conditioned in GA₃ and held in the standard preservative – nearly four times less than in the control and comparable to the initial content. Similar values were determined in lilies placed into the Floralife preparations after earlier conditioning with gibberellic acid. The amounts of free amino acids were higher than the initial level in tepals from all other treatments.

The content of free proline was the lowest and comparable to the initial value in tepals of lilies conditioned in GA₃ and placed into the standard preservative (Tab. 3). In flowers from all the other treatments the proline levels increased during vase life, up to twofold as compared to the initial content.

DISCUSSION

Lily longevity can be defined as inflorescence longevity as well as individual flower longevity (van der Meulen-Muisers et al. 1999). In experiments by van der Meulen-Muisers et al. (1999), flower longevity ranged between 2 and 10.8 days when evaluated in 45 Asiatic hybrid lilies. In ‘Rialto’ Oriental lily, individual flowers had a vase life of around 10 days, but the inflorescence longevity, assessed as the number of days from harvest until the fading of the second flower, reached 16 days. The vase life of both flowers was comparable, contrary to the results of Burchi et al. (2007) and Rabiza-Świder et al. (2015), who reported that the first flower lasted longer than the second and contradictory to studies by Kim et al. (2005) on LO and LA hybrids, where the younger flowers had longer longevity than the first (lowest) flower in an inflorescence.

Leaf yellowing is an early postharvest and postproduction symptom in lilies (Han 1997, 2001). In many cut flowers this problem is solved by retail florists by defoliating the shoots, but in lilies this practice is less common. Our earlier trials showed that the defoliating of cut lily stems does not improve the qualities of LA ‘Richmond’ (Rabiza-

Świder et al. 2015). It is advisable to use gibberellic acid on leafy lily stems, which assures the good postharvest performance of the foliage (Ranwala and Miller 2002, van Doorn 2011, Rabiza-Świder et al. 2015). In experiments by Ranwala and Miller (2002) on Asiatic hybrids, spray or pulse treatments with gibberellins prevented leaf chlorosis, with GA_{4+7} being more effective than GA_3 . According to Ranwala and Miller (1998), the best leaf protection against chlorosis in 'Star Gazer' lily was the foliar application of gibberellic acid in conc. of 100 mg d.m.⁻³. Our trials on 'Helvetia' confirmed that GA_3 (in conc. of 500 mg d.m.⁻³, used as a 24 h pulse treatment) prolonged foliage longevity 1.3-fold in comparison to untreated control leaves (Rabiza-Świder et al. 2012). A similarly positive effect was observed in LA hybrid 'Richmond', where GA_3 used continuously prolonged foliage life threefold relative to the control, from 20 to 60 days (Rabiza-Świder et al. 2015).

In this experiment, conditioning (24 h) with GA_3 (500 mg d.m.⁻³) immediately after harvest also delayed chlorophyll loss in the leaves of 'Rialto' cut oriental lily and prolonged their longevity. The most effective was combining the pulse treatment with GA_3 followed by placing lilies into preparations of the Floralife series (Floralife 200 and 300), where the foliage longevity was almost three times higher than that of the control leaves. This combination of postharvest treatments also prolonged the vase life of flowers, which was approximately 1.5-fold longer than in the control (flowers kept in water). The positive effect of gibberellins on lily flower longevity has been reported in LA 'Richmond' (Rabiza-Świder et al. 2015), in LO 'Siberia' and LA 'Dream Land' (Kim et al. 2005). However, the gibberellin effect on lily longevity is not always reported as positive. Pulsing 'Helvetia' Oriental lily with GA_3 generally did not increase the longevity of five successive flowers in the inflorescence, and neither did pulsing with BA or the mixture of GA_3 and BA (500 mg d.m.⁻³ each, 20 h) (Rabiza-Świder et al. 2012).

Nowak and Mynett (1985) were able to double the vase life of individual lily flowers by including sucrose in a holding solution. The positive role of the carbohydrates was confirmed by Song et al. (1996) on Asiatic hybrids. The experiments on 'Helvetia' lilies showed that the standard preservative composed of 8HQC and 2% sucrose significantly prolonged postharvest longevity relative to control flowers held in water, by 20% and 35% in the first and the fifth flower, respectively. Increased longevity

was associated with slowing down degradative processes, which was especially evident in the first flower (Rabiza-Świder et al. 2012). In 'Rialto' lily the standard preservative used after the GA_3 pulse treatment increased the individual longevity of both flowers as well as that of the entire inflorescence and this increase was the largest from all of the experimental treatments. The supplementation of sucrose to cut lilies resulted in an accumulation of the endogenous reducing sugars in tepals while the contents of free amino acids and free proline were the lowest. The data on endogenous sugars cannot be supported by the literature as it was obtained in this experiment.

Water stress induces the accumulation of free proline, which is regarded as a defence response as the amino acid increases cell tolerance to desiccation and stabilises the phospholipids of cell membranes (Karolewski 1996). Less free proline in the treated lily flowers could indicate less stress most likely due to improved water balances associated with an elevated osmoticum resulting from sugar accumulations in tepal cells.

Though beneficial for flowers, sugars from the holding solutions could aggravate symptoms of leaf senescence on cut stems. Pulse treatments with sucrose hastened the leaf yellowing of lilies after cold storage (Prisa et al. 2013). The presence of 2% sucrose in the holding solution negatively affected the leaf longevity of cut 'Helvetia' lily and hastened chlorosis as compared to stems held in water (Rabiza-Świder et al. 2012). The longevity of 'Richmond' leaves decreased with the use of the preservative containing 2% sucrose; however, the presence of GA_3 alleviated this negative sugar impact on the foliage. Sucrose also limited the positive effect of gibberellic acid on the postharvest condition of leaves of this hybrid (Rabiza-Świder et al. 2015). The same situation was observed in 'Rialto' lily. Using SP after GA_3 pulsing strongly limited the positive effect of gibberellic acid on the longevity of leaves which was, however, still 1.5-fold higher than that of control leaves but the lowest among all of the GA_3 treatments.

The commercial preparations of Floralife (Floralife 200 and Floralife 300) proved the most effective in delaying foliar chlorosis regardless of the GA_3 application. In addition, their influence on flower longevity was positive as the vase life of lilies treated with Floralife products was only 10-14% lower than that in the best treatment combination: GA_3 pulsing followed by SP. In conclusion, postharvest treatments with GA_3 together with

Floralife products are very effective in delaying the senescence processes and improving the keeping of the ornamental qualities of cut 'Rialto' lilies, therefore they can be recommended for use in each step of flower turnover for this cultivar.

CONCLUSIONS

1. Conditioning (24 h) with gibberellic acid (500 mg d.m.⁻³) immediately after harvest delayed chlorophyll loss in the leaves of 'Rialto' cut oriental lily and prolonged their longevity.
2. When combined with the standard preservative and commercial preparations Chrysal Professional 2 and Chrysal sachet as well as Floralife 200 and Floralife 300, GA₃ also prolonged flower vase life.
3. The best postharvest treatment that prolonged the vase life of flowers and improved the quality of leaves was the application of GA₃ followed by the Floralife series.
4. During the senescence of lilies held in water, the contents of reducing sugars and free amino acids, including proline, increased. The holding solutions modified these parameters.

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AUTHOR CONTRIBUTIONS

All authors contributed equally to this work. J.R.-Ś. designed and performed the experiments and wrote the paper, E.S. designed the experiments and equally contributed to manuscript writing, A.J. performed the analytical measurements and M.R. collected the data and performed statistical analyses.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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