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THE EFFECT OF GA_3 AND THE STANDARD PRESERVATIVE ON KEEPING QUALITIES OF CUT LA HYBRID LILY 'RICHMOND'

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Abstract. The aim of the experiment was to evaluate effects of gibberellic acid and the standard preservative (composed of 8HQC and sucrose) on keeping qualities of cut lily flowering shoots (*L. longiflorum* × Asiatic hybrid, 'Richmond'). These effects were tested in several experimental variants: the complete leafy shoot with the inflorescence (flowering shoot), inflorescence on a leafless shoot, decapitated leafy shoot, detached inflorescence and single leaves, in order to see how the components of a holding solution affect the particular plant organs on a lily flowering shoot. An experimental variant affected flower bud opening but less so the flower longevity. Keeping qualities such as vase life of lily flower and inflorescence, rate of bud opening and flower diameter were improved by the preservative only on a complete flowering shoot. Gibberellic acid as well the mixture of GA_3 plus the standard preservative prolonged longevity of flowers in all the experimental variants. Gibberellic acid delayed leaf yellowing which was in turn hastened by the preservative except in leaves on decapitated shoots. Leaf senescence was the earliest in detached single leaves.

Key words: flower longevity, postharvest treatments, sucrose, GA_3

INTRODUCTION

Lilies are one of the most important bulbous plants produced as cut flowers, pot plants and plant material used for park, garden and landscape decoration. The global production of lily bulbs occurs in 10 countries, the Netherlands having the largest production area with *ca* 4 000 hectares [Benschop et al. 2010]. The new groups of lily hybrids have been created during last 50 years due to the innovative hybrid breeding

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strategies so the assortment of lilies now consists of thousands of cultivars which are classified in different hybrid groups [van Tuyl and Arens 2011]. About 300 cultivars really count in global lily cut flower trade [van Doorn and Han 2011]. The customer's interest in the older Asiatic and Oriental hybrids massively grown since the 1970s has been declining while *Longiflorum* hybrids as well as *Longiflorum* × Asiatic (LA) crosses are gaining in importance. Also other hybrids are readily grown for cut flowers, such as the interspecific hybrids obtained from crosses between *Longiflorum* and Oriental hybrids (LO), between Oriental hybrids and Trumpet species (OT) or between Asiatic and Oriental hybrids (OA) [Grassotti and Gimelli 2011].

A global scale of flower trade demands that cut flowers should preserve their postharvest quality as long as possible, both during the market chain and at the consumer's.

Tepal wilting, change in colour and sometimes abscission are the common symptoms that limit the length of vase life of cut lilies [van Doorn and Han 2011]. Another major problem in postharvest life of lilies is early leaf yellowing [Han 1997, 2001, Leonard and Nell 2004] which can be overcome by the gibberellin application – alone or together with a cytokinin benzyladenine – on both, potted and cut lilies [Han 1997, 2001, Ranwala and Miller 1998]. It has recently been confirmed that pulsing of cut stems with GA_{4+7} plus BA extended vase life and prevented leaf chlorosis in Asiatic and Oriental hybrids of unstored lilies [Iftikar et al. 2014].

Nowak and Mynett [1985] were able to double vase life of individual lily flowers by including sucrose into a holding solution. The positive role of the carbohydrates was confirmed by Song et al. [1996] on Asiatic hybrids where the preservative was more effective on inflorescences harvested before opening of the first flower showing that immature buds are more dependant on carbohydrate supply. Studies of van der Meulen-Muisers and co-workers [2001] on detached lily flowering shoots suggest a competition for sugars between the buds within an inflorescence and show that intact buds can receive carbohydrates from other parts of a flowering shoot. Detached floral buds depend only on a limited supply of endogenous sugars present in tepals so their longevity is shortened relative to those left on plants or cut shoots.

Preservative solutions composed of sucrose and a biocide were invented for cut flowers over 50 years ago [Aarts 1957]. The search for new effective biocides has been continued ever since and different chemicals have recently been proposed for cut lilies [Kim et al. 2005, Kazemi and Ameri 2012, Nemati et al. 2013]. The most frequently used – because of its simplicity and efficiency – is a solution composed of 8HQC (or 8HQS) and sucrose [Larsen and Cromarty 1967, Halevy and Mayak 1981]. It is called "the standard preservative" and often used as a reference to compare effectiveness of other postharvest treatments.

Cut flowers differ in their ability to uptake and transport the exogenously applied carbohydrates, mainly sucrose or glucose. What is common is an accumulation of hexoses in petals of the sugar-fed flowers. However, individual parts of complex flowering shoots composed of stems, leaves and flowers play different roles in sugar translocation and accumulation in a flower/inflorescence which is the strongest metabolic sink [Bieleski 2000]. In roses leaves are an intermediary station for sugars from a holding solution and sometimes their hydrolysis and export towards the flower head is slower than accumulation what may result in a leaf blade necrosis. Depending on a species, sugars in

cut flowers can be translocated both as sucrose and glucose, by xylem and phloem, while sucrose hydrolysis is most intense in petals though invertase is also active in leaves and sucrose synthase in all flowers parts [Paulin 1997].

The aim of the experiment was to evaluate the effects of the floral standard preservative and gibberellic acid on cut flowering shoots of the relatively new LA hybrid 'Richmond' whose postharvest performance has not been described earlier. In lilies the term "cut flower" comprises a leafy shoot with an inflorescence composed of several flowers therefore, the effect of holding solutions on several flower parts was evaluated and compared in order to check how the particular organs of a flowering lily shoot compete for preservative ingredients and eventually influence each other's longevity. The inspiration for the above experimental scheme were the works of the Paulin's group on cut carnations [Paulin and Droillard 1982] and roses [Paulin and Bureau 1982] where a role of flower as a sink was studied and a participation of the different organs in sugar uptake and upward movement was compared – in the whole flowering shoots and in their individual parts. No such work was done on lilies where it would especially be interesting to compare a response to a flower preservative of the complete flowering shoots and those deprived of leaves whose presence is sometimes problematic during flower turnover.

MATERIAL AND METHODS

Cut flowering shoots of hybrid lily (*L. longiflorum* × Asiatic hybrid, LA 'Richmond') were used as the experimental material. Freshly harvested (in July), untreated stems were delivered to the laboratory by a local grower and immediately prepared for the experiment. Lilies were harvested when the first floral bud reached a "puffy" fully colored stage. Shoots were recut to 50 cm and leaves removed from the lowermost 10 cm shoot ends. Four flower buds were left on each shoot. Then lilies were divided into 5 groups, so called "experimental variant": I – complete flowering shoot (shoot + leaves + flowers), II – defoliated shoot (shoot + flowers), III – flowers (no leaves, 5 cm shoot), IV – flowerless shoot (shoot + leaves but no flowers) and V – detached leaves (from the middle shoot parts of model II). The part of flowering shoot were individually tagged and placed into vases with respective solutions. There were 10 single replications of each variant (placed into 2 vases) in each of the following treatment: 1. control (distilled water), 2. GA_3 0.1 mmol·dm^{-3} (34.6 mg·dm^{-3}), 3. the standard preservative (SP): sucrose 20 g·dm^{-3} + 8HQC 200 mg·dm^{-3}, 4. SP + GA_3. The following parameters were recorded: number of days till opening of the II and III flower bud, longevity of II and III flower, diameter of I, II and III flower, total longevity (number of days from the beginning of the experiment till fading of the IV flower), foliage longevity (number of days till the yellowing of 30% of leaf surface in a given treatment). The rate of bud opening is given as a number of days since the beginning of the experiment till the stage of open flower. The longevity is expressed as a number of days since bud opening till the appearance of deformations due to tepal withering. The diameter is expressed as the average of two measurements made in two perpendicular directions. The experiment was carried out in a chamber with controlled temperature (20ºC), light intensity

(35 $\mu mol \cdot m^{-2} \cdot sec^{-1}$, 12 hours per 24 hours and relative humidity 60%. The results were statistically evaluated by ANOVA 2 and the means compared by the Duncan's test at $\alpha = 0.05$.

RESULTS

The effects of a parts of flowering shoot and a bud age on the individual flower longevity in the shoots placed in water (control treatments) are compared in Table 1. The mean **longevity** of flowers standing in water was not affected by a parts of flowering shoot but depended on a flower age. In all three experimental variant the third flower (the younger one) had the longevity significantly shorter than the second flower. The largest difference in longevity between flower 2. and 3. occurred in the detached inflorescence where also the third flower had the shortest life – 11.2 days, i.e. 2.2 days less than the second flower of the same variant.

Table 1. Longevity (days) of the second and third flower in LA 'Richmond' held in water (control treatments)

Flower/variant	I[1]	II	III	Mean for flower
2.	13.2 d[2]	14.0 e	13.4 de	13.5 B
3.	11.9 b	12.5 b	11.2 a	11.9 A
Mean for variant	12.6 A	13.3 A	12.3 A	–

[1] – I – a complete flowering shoot (shoot + leaves + inflorescence); II – a defoliated shoot with the inflorescence; III – a detached inflorescence (5 cm shoot)
[2] – means followed by the same letter do not differ at $\alpha = 0.05$

The mean **longevity** of the third flower was significantly shorter in the detached inflorescence (variant III) (tab. 2). All the treatments significantly prolonged it. In all the variant flower longevity was increased by GA_3 as compared to water control. In two cases this was also evident relative to the preservative (variant II and III). In variant I (the complete flowering shoot) every treatment prolonged flower vase life, the preservative even more than GA_3. The joint application of the preservative and gibberellic acid on this variant was significantly more effective than any of them used separately and resulted in the increase of flower longevity by over 4 days relative to the respective water control (tab. 2).

The parts of flowering shoot did not affect the average lily **total longevity** which in turn was affected by the treatments (tab. 3). The standard preservative significantly increased longevity (by 2.1 days relative to the control) only in variant I (complete shoot) while the gibberellic acid prolonged vase life in all the cases: by 3.6–5.4 days when applied as a water solution and by 3.7–6.2 days when used together with the stan-

dard preservative. In neither variant a synergistic action of the preservative and GA_3 was evident and there were no significant differences between an average longevity of lilies from treatment 2 (GA_3 in water) and 4 (GA_3 in the preservative solution).

Table 2. Effect of treatment and experimental variant on longevity (days) of the 3. flower in the inflorescence of the LA 'Richmond'

Treatment/variant	I[1]	II	III	Mean for treatment
H_2O	11.9 ab[2]	12.5 b	11.2 a	11.9 A
$H_2O + GA_3$	13.8 c	15.1 d	13.3 c	14.1 C
8HQC + S	15.5 d	12.5 b	11.6 ab	13.2 B
8HQC + S + GA_3	16.3 e	15.2 d	13.7 c	15.1 D
Mean for variant	14.4 B	13.8 B	12.3 A	–

[1, 2] – explanations as in table 1

Table 3. Effect of treatment and experimental variant on total LA 'Richmond' lily longevity (number of days till fading of the fourth flower)

Treatment/variant	I[1]	II	III	Mean for treatment
H_2O	21.4 a[2]	21.6 a	20.1 a	21.0 A
$H_2O + GA_3$	25.0 bc	26.5 c	25.5 c	25.7 C
8HQC + S	23.5 b	21.0 a	21.8 a	22.1 B
8HQC + S + GA_3	25.5 c	25.3 c	26.3 c	25.7 C
Mean for variant	23.8 A	23.6 A	23.4 A	–

[1, 2] – explanations as in table 1

The effects of both experimental factors (the parts of flowering shoot and the treatment) on the **rate of flower opening** were similar for the second and third bud therefore only the results for the third flower are presented. Both, the parts of flowering shoot and the treatments had the significant effect on rate of bud opening (tab. 4). The bud from the detached inflorescence needed on the average more days till full opening than buds of two other variants. The number of days till opening of the third flower stored in water was 3.8–5.6 and did not vary significantly. This parameter remained unaffected by the holding solutions for the buds on defoliated shoots and in detached inflorescences. However, in complete flowering shoot the use of the preservative solution hastened bud development and decreased the number of days till full flower opening to 2.0, significantly less than in a given control.

The mean **diameter** of the oldest (first) flower did not vary among the parts of flowering shoot and neither treatments affected it within the variants (data not presented). The effects of both experimental factors (the parts of flowering shoot and the treatment) on flower diameter were similar for the second and third bud therefore only the results

for the third flower are presented (tab. 5). Both experimental factors significantly affected flower diameter: the detached inflorescences (5 cm shoot) had flowers with the significantly smaller mean diameter than had the flowers on the complete flowering shoot. A joint application of the preservative and GA_3 significantly increased the mean flower diameter. In neither of the experimental variants GA_3 when used alone increased the flower diameter relative to the respective water control. The standard preservative was effective only in complete flowering shoots. The joint application of GA_3 and SP increased diameter in this variant and in detached inflorescences, by 10% on the average as compared to the respective controls. Similar results were observed in the second flower (data not presented) where the mean diameter was also increased by the joint use of the solution composed of GA_3 and SP (18.3 cm as compared to 17.6 cm in control) and the complete flowering shoots produced flowers significantly larger than detached inflorescences (18.1 cm *versus* 17.6 cm, on the average).

Table 4. Effect of treatments and experimental variant on the number of days till opening of the third flower of LA 'Richmond'

Treatment/variant	I[1]	II	III	Mean for treatment
H_2O	4.9 cd[2]	3.8 abcd	5.6 d	4.8 B
$H_2O + GA_3$	3.5 abc	4.4 bcd	5.0 cd	4.3 AB
8HQC + S	2.0 a	4.1 bcd	4.5 bcd	3.5 A
8HQC + S + GA_3	2.8 ab	4.1 bcd	5.4 cd	4.1 AB
Mean for variant	3.3 A	4.1 A	5.1 B	–

[1, 2] – explanations as in table 1

Table 5. Effect of treatments and experimental variant on the diameter (cm) of the third flower of LA 'Richmond'

Treatment/variant	I[1]	II	III	Mean for treatment
H_2O	17.5 abc[2]	17.4 abc	16.8 a	17.2 A
$H_2O + GA_3$	17.0 a	17.6 abcd	17.2 ab	17.2 A
8HQC + S	18.6 de	17.4 abc	17.3 abc	17.7 A
8HQC + S + GA_3	19.4 e	18.1 bcd	18.4 cde	18.6 B
Mean for variant	18.1 B	17.6 AB	17.4 A	–

[1, 2] – explanations as in table 1

Generally, the part of flowering shoot affected mean **foliage longevity**. The leaves on the complete flowering shoot (variant I) characterized with the longest longevity, while the shortest life had the single, detached leaves (variant V) (tab. 6). Gibberellic acid prolonged threefold the mean foliage life and its effect was the largest in decapitated shoots (354% relative to water control). The preservative tended to shorten it – by

Table 6. Foliage longevity (days) of LA 'Richmond' depending on a treatment and experimental variant

Treatment./variant	I[1]	IV	V	Mean for treatment
H_2O	19.4 c[2] (100%)	15.5 b (100%)	16.0 b (100%)	17.0 B
$H_2O + GA_3$	60.9 i (314%)[3]	54.9 h (354%)[3]	48.3 f (302%)[3]	54.7 D
8HQC + S	12.9 a (66%)	17.0 b (110%)	12.9 a (81%)	14.3 A
8HQC + S + GA_3	51.0 g (263%)	44.5 e (287%)	35.5 d (222%)	43.7 C
Mean for variant	36.0 C	33.0 B	28.2 A	–

[1] – I – a complete flowering shoot; IV – a leafy shoot without inflorescence; V – single detached leaves
[2] – means followed by the same letter do not differ at $\alpha = 0.05$
[3] – percentage of a given control (H_2O)

19% and 34% in single leaves and complete shoots, respectively. The exception was the flowerless shoots held in the solution 8HQC + S where the 10% increase in leaf longevity was observed. In each experimental variant the preservative decreased GA_3 efficiency by 51–80%.

DISCUSSION

Postharvest longevity of cut lilies is a function of floral bud number on an inflorescence and a life span of individual flowers. These two desirable features are negatively correlated as found by van der Meulen-Muisers et al. [1998] in their studies on 63 lily genotypes, mostly Asiatic hybrids. Lily longevity can be defined as an inflorescence longevity as well as individual flower longevity. Individual flower longevity has been used as a selection criterion in breeding programs whose main goal is improving postharvest performance of the lily inflorescences [van der Meulen-Muisers et al. 1999]. Two criteria to define the end of life of Asiatic lily flowers were compared in 35 lily genotypes by van der Meulen-Muisers and Oeveren [1997]: a loss of turgor by the tepals or tepal deformations due to withering. The latter parameter was adopted as a better criterion for the termination of flower longevity and as such it was used in the present experiment. In tests of van der Meulen-Muisers et al. [1999] flower longevity ranged between 2 and 10.8 days when evaluated in 45 progenies of seedlings and clones of Asiatic hybrid lilies. The above values are plant means which were determined from data collected on all flowers per plant and divided by a number of flowers. Such a procedure does not allow to see differences in longevity between the most mature (the lowest) flowers and the younger buds on top of the shoot. In LA 'Richmond' the third flower had the longevity shorter than the second flower in all the experimental variants. Similar situation was found in detached flowers of Asiatic cultivars where the first flower lasted longer while the third had the shortest life [Burchi et al. 2007]. The phenomenon was explained by the authors as due to a competition for carbohydrates be-

tween the buds on the shoots and lack of substrate availability in detached single flowers. Opposite was observed in studies of Kim et al. [2005] on LO and LA hybrids where the younger flowers had longevity longer than had the first (lowest) flower in an inflorescence.

A difference in longevity between individual detached flowers and those left intact on inflorescences proved a dependence of this parameter on the tepal carbohydrate status in studies of van der Meulen-Muisers et al. [2001] on Asiatic hybrid lilies. While the longevity of flowers left on the inflorescence remained constant the buds detached from the shoots varied in size and in carbohydrate contents and those of a critical size (60 mm) developed into flowers of a shorter longevity than the lowermost ones or failed to open.

According to van der Meulen-Muisers and Oeveren [1997] the developmental stage of the floral buds at harvest affect lily longevity. Lilies of 'Richmond' were harvested in fully colored, puffy stage of the first bud. As its development was more advanced under the greenhouse environmental conditions than that of other buds, its longevity was not compared to that of the next two flowers on the shoot whose opening occurred under the experimental conditions. Generally, the longevity of the third bud and that of the whole inflorescence little depended on the "experimental variants" being comparable on a complete leafy shoot and defoliated shoot and a little inferior in detached inflorescence (5 cm shoot). No difference in longevity between flowers from leafy or defoliated shoots was also reported by Han [2003] in her trials on Oriental lily 'Stargazer'. However, in LA 'Richmond' the holding solutions modified this parameter, GA_3 being generally more efficient in prolonging flower vase life than the standard preservative. What's surprising, the positive effects of the sucrose containing preservative were found only in a complete flowering shoot which probably had the best carbohydrate and hormonal balance among the variants tested. Probably, leaves play an important role in sugar translocation within the flowering lily shoot, similarly as in roses [Paulin and Bureau 1982]. In the same variant the preservative hastened bud opening similarly as observed by Arrom and Munne-Bosch [2012].

The esters of 8-hydroxyquinoline (citrate and sulfate) had already been included into the preservative solutions nearly 50 years earlier [Larsen and Cromarty 1967]. The solution of 8HQC together with sucrose is called "a standard preservative" and used in trials on different cut flowers as a reference solution. It increased longevity of each of 5 flowers on cut shoots of Oriental lily 'Helvetia' [Rabiza-Świder et al. 2012]. Earlier Han [2003] reported that the same standard preservative neither affected the longevity nor flower diameter in another Oriental lily 'Stargazer' enhancing in turn the anthocyanin content in tepals. Now we report that it improved keeping qualities of cut LA 'Richmond' such as longevity of the third flower, total inflorescence longevity, the rate of the bud opening and the flower diameter but only on a complete leafy shoots. Opposite was observed in *Alstroemeria* where florets on defoliated shoots responded better to a preservative than those on shoots with leaves [Yeat et al. 2012]. In two other 'Richmond' parts of the flowering shoot – the inflorescence on a leafless shoot and shootless inflorescence – the effect of this preservative was inferior to that of gibberellic acid or needed its presence to be an effective holding solution. Arrom and Munne-Bosch [2012] showed that sucrose in a holding solutions affects lily flower development through

a hormonal effect therefore we can speculate that the response to exogenous sucrose of 'Richmond' lilies was somehow related to a hormonal balance in their cut shoots, probably diversified in our "experimental variants" by decapitation and/or defoliation.

Gibberellins may be applied on cut lilies by pulsing, spraying or as continuous feeding with the growth regulator applied either in water or in a holding solution [Han 2001]. Gibberellin treatments (pulsing or spraying) increased inflorescence longevity in Asiatic lily hybrids and GA_{4+7} at 100 mg·dm^{-3} was more effective than GA_3, either when applied alone or in combination with BA as the commercial preparation Promalin [Ranwala and Miller 2002]. The increase in flower longevity was due to a delay of bud opening and increased longevity of flowers. The same was confirmed in LA 'Richmond' held in the GA_3 water solution. In LO 'Siberia' and LA 'Dream Land' for longevity prolongation GA_{4+7} was more effective than GA_3 either when applied as water solution or in Promalin, either by dipping or spraying [Kim et al. 2005]. However, not always the gibberellin action on lily longevity is reported as positive. Pulsing Oriental lily 'Helvetia' with GA_3 generally did not increase longevity of five successive flowers in the inflorescence, neither did pulsing with BA nor the mixture of GA_3 and BA (500 mg·dm^{-3} each, 20 h) [Rabiza-Świder et al. 2012]. The concentrations used in the latter experiment may have been too high similarly as in the trials of Ranwala and Miller [2002] where flowers buds of three Asiatic hybrids failed to open after the 500 mg·dm^{-3} GA_{4+7} treatment.

Leaf yellowing is an early postharvest and postproduction symptom in cut and potted lilies, respectively [Han 1997, 2001]. In cut alstroemerias this problem is solved by the retail florists by defoliating the shoots but in lilies this practice is less common. LA 'Richmond' has dense, dark green and shiny foliage and its removing would impair decorative value of cut shoots. Already in 1976 Staden reported that including a gibberellin and kinetin into a vase solution had delayed leaf senescence in cut lilies. Supplementation of the standard preservative with GA_3 (50 mg·dm^{-3}) prevented leaf yellowing in cut Asiatic hybrids [Song et al. 1996]. Han [1997] prevented foliar chlorosis in potted Easter lilies by spraying plants with combinations of benzyladenine and GA_{4+7}. The same growth regulators applied by spraying, pulsing or as a continuous treatment in a vase solution [Han 2001] or applied as a preparation Promalin [Celikel et al. 2002] prevented leaf yellowing in cut Oriental and Asiatic lilies, whether cold-stored or not. In trials of Ranwala and Miller [2002] on Asiatic hybrids, spray or pulse treatments with gibberellins prevented leaf chlorosis, GA_{4+7} being more effective than GA_3. GA_3 applied as a pulse treatment (500 mg·dm^{-3}, 20 h) increased leaf longevity in oriental lily 'Helvetia', by 35 and 59% when used alone or together with BA, respectively [Rabiza-Świder et al. 2012]. Gibberellic acid dramatically increased longevity of leaf in LA 'Richmond' in all three different "experimental variants", over three-fold relative to respective controls. The foliage on a complete shoot lasted the longest, i.e. over 60 days but an increase in longevity due to GA_3 was even more pronounced in decapitated shoot (354 *versus* 314%). As shown by Arom and Munne-Bosch [2012] lily flowers produce more auxins and cytokinins in response to presence of exogenous sucrose in a vase solution. Lack of these hormones might have shortened foliage longevity on decapitated shoots of our LA hybrid stored in water as compared to complete leafy shoots. The leaves only in this variant did not show a detrimental effects of sucrose from the stan-

dard preservative. Probably having no sink formed usually by flowers they absorbed less water and less sucrose from the holding solution. Also the transpirational stream might have been weaker what led to less sugar being accumulated in leaves.

Sugars from holding solutions aggravate symptoms of leaf senescence in cut flowers. Also pulse treatments with sucrose hasten leaf yellowing of lilies after cold storage [Prisa et al. 2013]. In roses Paulin [1979] showed that sucrose uptaken from a holding solution accumulates in the apoplast of leaves during its transport towards the flower, before being hydrolyzed to reducing sugars. Excess of disaccharide at the vessels ends draws water from mesophyll cells causing their collapse and tissue necrosis. This conclusion was supported by Markhart III and Harper [1995] whose ultrastructural observations showed mesophyll plasmolyzed cells in rose leaves from shoots held in the preservative solution composed of 8HQC and sucrose in concentrations ranging from 0.25 to 2%. A degree of leaf crisping and tissue damage was correlated with the amount of sugar in the vase solution. From the other side, it has recently been confirmed that rose leaves actively convert exogenous glucose to sucrose and play an important role in transportation of exogenous sugars towards the petals contributing to a better postharvest rose quality [Horibe et al. 2014]. The importance of leaves as 'recycling pump' in the process of uptake and transport of exogenous sugars by cut roses and carnations was stressed by Sacalis and Durkin already in 1972.

Endogenous sugar levels were not measured and compared in the present study therefore it is not possible to speculate on the uptake, transport and remobilization of sugars in cut lily flowers. Such determination could be done in similar experimental variants as presented here but more detailed analyses should be performed as those whose results have been reported so far, do not distinguish between different petal tissues, cells or cell compartments. The question if the petal senescence is due to sugar starvation has not been answered though it was posed more than a decade ago [van Doorn 2004]. There is still a lack of data as to distribution of endogenous carbohydrates in various petal tissues and their levels in various cell types and their compartments though this problem was signaled by van Doorn already in 2001.

The phenomenon of a flower being a powerful sink, a role phloem in sugar transport, mechanism of its loading and unloading in petal tissues in relation to flower development and death [Bieleski 2000] remain unanswered questions though the studies on a fate of exogenous sugars supplied to cut flowers with the preservative solutions have been carried out for decades. The importance of leaves as 'recycling pump' in the process of uptake and transport of exogenous sugars by cut roses and carnations was stressed by Sacalis and Durkin already in 1972. Works of Sacalis and Chin [1976] on metabolism of sucrose in cut roses indicated a rapid turnover of sugars in shoots and moderate in leaves. The next phase of studies revealed that labeled sucrose is laterally moved from xylem to phloem in rose stem and that this sugar undergoes a complex pattern of hydrolysis where invertase plays a regulatory role in two areas: in xylem and in receptacle or petals where reducing sugars predominate [Chin and Sacalis 1977a]. In their successive work the team proved that sucrose from a holding solution may be absorbed undegraded by the rose petals and that inversion is not prerequisite for this process [Chin and Sacalis 1977b]. The mechanism of glucose and sucrose uptake by cut roses and carnations and a role of cut flowers parts such as shoots, leaves and flowers in

the above process have been studied by the Paulin's team in 70-ties and 80-ties of XX age [Paulin 1979, Paulin and Bureau 1982, Paulin and Droillard 1982] summarized by Paulin in his book [1997].

Longevity of 'Richmond' leaves was decreased by the use of the preservative containing 2% sucrose. Presence of GA_3 alleviated this negative sugar impact on the foliage or sucrose limited a positive effect of gibberellic acid on postharvest condition of leaves. The mean leaf longevity was the smallest in single detached leaves, devoid of both, endogenous carbohydrates stored in shoots and hormones coming from flowers. Neither the treatment with gibberellin nor a joint application of the preservative and GA_3 could prolong life of these leaves comparably to a life span in two other models.

In conclusion, defoliating cut lily stems – performed by the florists to avoid unsightly symptoms of premature leaf senescence – does not improve keeping qualities of LA 'Richmond'. It is advisable to use a floral preservative on leafy stems of LA hybrids on condition that a treatment with gibberellic acid which assures good postharvest performance of the foliage will be used.

CONCLUSIONS

1. Keeping qualities of cut lily 'Richmond' depended on the particular organs of a flowering shoot and generally were the poorest in detached inflorescences and leaves. Flower longevity depended as well on a flower age (position on a stem) and a holding solution.

2. The standard preservative composed of 8HQC (200 $mg \cdot dm^{-3}$) and sucrose (20 $g \cdot dm^{-3}$) improved lily keeping qualities only in complete leafy inflorescences.

3. Regardless of treatment (in water or in the preservative solution) GA_3 prolonged total longevity of lily flowers whose diameter was increased only due to a joint application of gibberellin and the standard preservative.

4. Gibberellic acid delayed leaf yellowing which was in turn hastened by the preservative except in leaves on decapitated stems; GA_3 efficiency in delaying leaf senescence was decreased by the preservative.

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WPŁYW GA_3 I POŻYWKI STANDARDOWEJ NA POZBIORCZĄ TRWAŁOŚĆ CIĘTYCH KWIATÓW LILII MIESZAŃCA LA 'RICHMOND'

Streszczenie. Celem badań było określenie wpływu kwasu giberelinowego i pożywki standardowej (zawierającej 8HQC i cukier) na trwałość ciętych kwiatów mieszańca LA lilii 'Richmond' (mieszaniec *L. longiflorum* z lilią azjatycką). Wykorzystano kilka warian-

tów: kompletny ulistniony pęd kwiatostanowy, kwiatostan na pędzie pozbawionym liści, ulistniony pęd pozbawiony kwiatostanu, odcięty kwiatostan i pojedyncze liście, by sprawdzić, jak składniki pożywki wpływają na poszczególne elementy pędu kwiatostanowego lilii. Wykazano, iż doświadczalny wariant ciętej lilii wpłynął na trwałość kwiatów w kwiatostanie i w mniejszym stopniu na ich rozwój. Pożywka standardowa przedłużyła trwałość kwiatów tylko w przypadku kompletnego pędu kwiatostanowego. Zastosowanie GA_3 – samego bądź w połączeniu z pożywką standardową – przedłużyło trwałość kwiatów, bez względu na rodzaj modelu kwiatu. GA_3 opóźnił również starzenie liści, które było wyraźnie szybsze po zastosowaniu roztworu 8HQC z 2% sacharozą, z wyjątkiem kombinacji, gdzie usunięto kwiatostan. Szybkość starzenia się liści uzależniona była od zastosowanego wariantu – najszybciej dekoracyjność traciły odcięte, pojedyncze liście.

Słowa kluczowe: trwałość kwiatów, zabiegi pozbiorcze, cukier, GA_3

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