ACTA SCIENTIARUM POLONORUM Acta Sci. Pol. Hortorum Cultus, 21(4) 2022, 83–89

https://czasopisma.up.lublin.pl/index.php/asphc ISSN 1644-0692 e-ISSN 2545-1405 https://doi.org/10.24326/asphc.2022.4.9

ORIGINAL PAPER

Accepted: 4.03.2022

MORPHOLOGICAL AND MECHANICAL PROPERTIES OF *Strelitzia reginae* FLOWERS DEPENDING ON THE SOLUTION USED FOR CONDITIONING

Paweł Szot[1], Elżbieta Pogroszewska[1], Danuta Kozak[1], Barbara Marcinek[1], Marzena Parzymies[1] ✉, Margot Dudkiewicz[2], Katarzyna Rubinowska[3]

[1] Subdepartment of Ornamental Plants and Dendrology, Institute of Horticultural Production, University of Life Sciences in Lublin, Poland

[2] Department of Landscape Architecture, University of Life Sciences in Lublin, Poland

[3] Department of Botany and Plant Physiology, University of Life Sciences in Lublin, Poland

ABSTRACT

Strelitzia reginae is an important cut flower native to South Africa. The effect of silicon and gibberellic acid with sucrose as conditioners on the post-harvest quality of *Strelitzia* cut flowers was investigated. Inflorescence shoots were conditioned for 24 hours in: water solutions of Actisil 0.2% or gibberellic acid (GA_3) – 200 mg·dm^{-3} + sucrose 10% or distilled water (control). The shoots were then placed in distilled water or Chrysal Clear Professional 2 (10%). It was found that GA_3 + sucrose and Actisil increased the size of orange sepals and blue petals when after conditioning, the shoots were placed in water or Chrysal. Conditioning in Actisil and storage in Chrysal increased the value of mechanical parameters of flowers, leading to greater flexibility and lower susceptibility to fracture. Conditioning the shoots in Actisil and keeping them in Chrysal extended the life of flowers by 2 days.

Key words: Actisil, bird of paradise, Chrysal, gibberellic acid, mechanical damage, post-harvest, vase longevity

INTRODUCTION

Strelitzia reginae, a sub-tropical herbaceous plant native to South Africa, is widely used as a flower crop. The plants form inflorescences of exotic appearance. Each flower has 3, upright orange outer tepals and 3 modified blue inner tepals [Kew Species Profiles]. The inflorescence consists of 4–6 flowers, from which only some develop [Reinten et al. 2011]. The durability of the inflorescence is 6–16 days [Bayogan et al. 2008]. As an ornamental plant it is intended for ceremonial, personal or commercial use and therefore the decorative value and quality requirements of the plant play an important role [Zaidi et al. 2016, Sajjad et al. 2017]. In the case of ornamental cut flowers, longevity seems a deciding feature. Preparations recommended for prolonging the post-harvest duration of *Strelitzia* flowers usually contain sucrose. According to Finger et al [1999, 2003], conditioning shoots in 40% sucrose solution for 24 hours extends the period of inflorescence decoration by increasing the number of open flowers. The treatment of inflorescences with a sucrose solution at a lower concentration (5%) is also beneficial [Bayogan et al 2008]. To maintain the highest quality of *Strelitzia* flower inflorescences after cutting, it is proposed to use

✉ marzena.parzymies@up.lublin.pl

media, in which the sucrose content is 10% [Jaroenkit and Paull 2003, Hassan 2009]. Maintenance of cut flowers of many plant species in an optimal condition at all marketing stages is often ensured by the Chrysal Clear Professional series [Balas et al. 2006], which may be additionally supplemented with gibberellic acid. The post-harvest application of gibberellic acid positively affects the quality of *Strelitzia* flowers [El-Saka et al. 1995].

The mechanical strength of is another feature that determines the quality of cut flowers [Zhao et al. 2013]. It plays a role to the stems or flowers bending and breaking, which may occur during storage and handling [Chen 2003]. According to Onoda et al. [2015], leaves should be stiff and strong to maintain mechanical stability. Mechanical damage may also occur to flowers in the form of abrasion, cutting surface, kneading, and tearing of petals [Dias et al. 2013]. In the case of *Strelitzia*, the inflorescence shoots are ready for harvest when the orange sepals are visible at the top of the bract [Criley and Paull 1993]. Undeveloped inflorescences require opening. It is possible to cut shoots at a more advanced stage of inflorescence development, but then the flowers are more vulnerable to damage [Bayogan et al. 2008]. Mechanical strength of plant tissues may be enhanced with the use of growth stimulators containing active silicon, such as Actisil preparation [Kamenidou et al. 2008, 2010, Zhao et al. 2013, Whitted-Haag et al. 2014]. It may also enhance the better quality and post-harvest longevity of stems [Wraga and Dobrowolska 2008, Kazemi 2012, Kazemi et al. 2012c].

The purpose of the experiment was to investigate the effect of silicon and gibberellic acid (GA_3) used together with sucrose as a conditioner for post-harvest treatment of *Strelitzia* flower shoots, on the post-harvest quality of flowers assessed by their morphological characteristics and mechanical properties.

MATERIALS AND METHODS

The research material consisted of inflorescence shoots of *Strelitzia reginae* Banks ex Aiton obtained from plants cultivated in a glasshouse, in the ground, with the natural light. The inflorescence shoots were cut in the phase of the first developed flower, just before the development of the second flower (visible color). Shoots were cut to the length of 80 cm and conditioned in the following solutions:

1. Water solutions of Actisil containing 0.6% of silicon in the form of H_4SiO_4; the concentration of Actisil was 0.2%, being an equivalent of 120 mg Si·dm^{-3},
2. Gibberellic acid (GA_3) water solution – 200 mg·dm^{-3} + sucrose 10%,
3. Distilled water (control).

The conditioning took 24 hours in a growing room with controlled thermal-light conditions: temperature 20 ±1°C, relative air humidity 60%, light intensity PPFD 35 μmol·m^{-2}·s^{-1} with a photoperiod of 12 hours of light and 12 hours of darkness. After conditioning, the shoots were placed in distilled water or in Chrysal Clear Professional 2 (10%) under the same conditions. There were 15 inflorescence shoots per treatment with 3 repetitions.

After 5 days of storage, the following morphological characteristics of flowers were determined: length and width of the green bract, length of orange sepals (cm), length of dark blue petals together measured with the stigma (cm), length of the receptacle (cm), cross-sectional area of the receptacle above the ovary (mm^2) – Figure 1, as well as mechanical properties of the first 3 flowers in the inflorescence on 5 inflorescence shoots. Another 10 inflorescences in each combination were separately marked and treated as replicates served to test their durability. The moment, when petals began to discolor or dry out, was assumed as the loss of decorative value.

Measurements of mechanical properties of plant material were carried out on the Zwick BDO-FB 0.5H strength device. Examining the mechanical properties of flowers, the maximum force was determined, causing the receptacle to break under static conditions and deformation and energy at the above-mentioned maximum force. For the tests, single flowers taken out from the inflorescence were placed in a holder, and then bent by pressing the arm at a speed of 50 mm·min^{-1} just above the ovary, in the place of the narrowing (Fig. 1). The force at which the irreversible damage to the tissue was done was estimated.

Results of the study were statistically analyzed using the ANOVA analysis of variance for two factorial orthogonal classification. The significance of differences between means was estimated using T-Tukey confidence intervals at the significance level of

Fig. 1. The morphological characteristics of a flower: 1 – length of orange sepals, 2 – length of blue petals, 3 – length of the receptacle, 4 – place of the maximum force measurement

$\alpha = 0.05$. The statistical analyses were performed using Statistica 13.0 (StatSoft, Cracow, Poland).

RESULTS AND DISCUSSION

The effect of Actisil silicon solution, GA_3, and Chrysal, on *Strelitzia* inflorescence size was noted. Conditioning shoots in GA_3 + sucrose 10% solution and then inserting them to Chrysal, resulted in a lengthening of the green bract (21.9 cm) in comparison to control shoots (19.0 cm) – Table 1. The beneficial influence of all the treatments on the size of orange sepals and blue petals was also proved, in comparison to the control (Tab. 2).

The positive effect of different biostimulation solutions on the growth and development of other plant species was proved by many authors. Silicon application increased the flower diameter of *Paeonia lactiflora* [Zhao et al. 2013], length of petals in *Alstroemeria* [Yeat et al. 2012], and lily (*L. longiflorum* × Asiatic hybrid, 'Richmond') [Song et al. 1996]. The longest petals and sepals of *Strelitzia* were observed when inflorescence shoots were conditioned in GA_3 + sucrose solution and stored in Chrysal. Similar results were noted by El-Saka et al. [1995] in *Strelitzia reginae* and by Szot [2010] in tulips.

The treatments used during conditioning and storage influenced the post-harvest longevity of inflorescences as well (Tab. 2). The vase life of *Strelitzia* flowers was the shortest in the case of the control flowers, conditioned and stored in water (6.1 days). Significantly longer storage life was noted when inflo-

Table 1. The influence of H_2O, Actisil, GA_3 conditioning treatments on morphological features of cut *Strelitzia reginae* flowers

Conditioning 24 hours (A)	Storage 5 days (B)	Length of green bracts (cm)	Mean for A	Width of green bracts (cm)	Mean for A	Length of the receptacle (cm)	Mean for A
H_2O (control)	H_2O	19.0a*	19.4A	2.7a	2.8A	5.0a	5.2A
	Chrysal	19.8ab		2.9a		5.3a–c	–
Actisil	H_2O	19.6ab	19.1A	2.9a	2.9A	5.1ab	5.4A
	Chrysal	18.6a		2.9a		5.6bc	–
GA3 + sucrose	H_2O	20.1ab	21.0B	2.8a	2.9A	5.6bc	5.7B
	Chrysal	21.9b		3.1a		5.7c	–
Mean B	H_2O	19.6A		2.8A		5.2A	
	Chrysal	20.1A		2.9A		5.5A	

* Means followed by the same letter do not differ significantly at α = 0,05.

Table 2. The influence of H_2O, Actisil, GA_3 conditioning treatments on morphological features and vase life of cut *Strelitzia reginae* flowers

Conditioning 24 hours (A)	Storage 5 days (B)	Length of blue petals (cm)	Mean for A	Length of orange sepals (cm)	Mean for A	Vase life of the flowers (days)	Mean for A
H_2O (control)	H_2O	10.4a*	10.9A	10.7a	11.1A	6.1a	6.9A
	Chrysal	11.2bc		11.4b	–	7.6bc	
Actisil	H_2O	11.1bc	11.1A	11.4b	11.4AB	7.6bc	7.9A
	Chrysal	11.0b		11.3b	–	8.2c	
GA3 + sucrose	H_2O	11.0b	11.3A	11.5b	11.6B	6.7ab	6.8A
	Chrysal	11.5c		11.7b	–	6.8ab	
Mean B	H_2O	10.8A		11.2A		11.2A	
	Chrysal	11.2B		11.5A		11.5A	

* Means followed by the same letter do not differ significantly at α = 0,05.

rescence shoots were conditioned in Actisil and stored in water (7.6) or Chrysal (8.2) or conditioned in water and stored in Chrysal (7.6).

Commercial preparations, like Chrysal, are often used for conditioning and storage of cut plants. They contain nutrients, anti-ethylene agents, bactericides, fungicides, and hormonal substances. They improve water conductance, lower pH of the solution, inhibit chlorophyll degradation, provide nutrients [Rabiza-Świder et al. 2015], and delay the degradation of soluble proteins [Rabiza-Świder et al. 2012]. The sucrose water solution is also often recommended to extend the vase life of cut flowers. Koley et al. [2017] noted that 2% sucrose with 300 mg·dm^{-3} $Al_2(SO_4)_3$ increased the number of florets opened per stem, vase life, and other post-harvest traits in *Strelitzia*. Insertion of flower shoots into the 5% sucrose solution had a beneficial effect on the stability of the inflorescences after cutting. It was also beneficial to use a mixture of 10% sucrose, 250 mg·dm^{-3} 8-hydroxy-2-quinoline-carboxylic acid (8HQC), and 10 mg·dm^{-3} $AgNO_3$ for 24 h [Bayogan et al. 2008]. According to Arrom and Munné-Bosch [2012], sucrose in the solution exerts an influence on flower tissue. The addition of 2% sugar significantly increased the opening of small Oriental Lily 'Stargazer' buds [Han 2003]. The author recommends, in addition to inserting flower shoots into a 2% sucrose solution, the use of leaf spraying with gibberellic acid. This kind of combination treatment with growth regulators considerably increased the quality of *Lilium* 'Alma Ata' too [Krstulović et al. 2018]. The mixture of 10% sucrose with GA_3 in the present experiment, however, did not increase the post-harvest flower stability.

The longest vase life of *Strelitzia* flowers in the presented experiment was noted when shoots were conditioned in Actisil, however, the difference was not significant. The beneficial effect of conditioning the cut flowers in silicon solution for their post-harvest durability was reported by Kazemi et al. [2012a] in *Dianthus caryophyllus*, Kazemi et al. [2012b] in rose, Kazemi [2012] on *Argyranthemum*, Kazemi et al. [2012a] in *Eustoma grandiflorum*. The beneficial effect of silicon may be related to increasing the resistance of plants to water stress (improving water use, osmoregulation, and reducing transpiration) [Sacała 2009], and as Babak and Majid [2011] stated, inhibiting the influence of silicon on ethylene production, as well as silicon counteracting the oxidative stress in the cell [Sacała 2009], and retardation of chlorophyll as well as carbohydrate degradation during the post-harvest life [Kazemi et al. 2012a]. In addition, silicon can form complexes with organic components of epidermal cell walls, thereby enhancing their resistance to enzymes produced during aging [Snyder et al. 2007].

The applied preparations affected the mechanical properties of *Strelitzia* flowers (Tab. 3). It was noted that they were more resistant to the destruction maximum force when the inflorescence shoots were conditioned in Actisil (9.6 mm) in comparison to the control (8.3 mm) and to the deformation force when inflorescence shoots were conditioned in Actisil (4.3 mm) or GA_3 + sucrose solution (4.2 mm) in comparison to the control (3.7 mm). The obtained values of mechanical properties parameters indicate that the above treatments allow obtaining flowers characterizing with greater flexibility, less fragile, and thus less susceptible to breaking during storage, packaging, and handling. This elasticity of tissues can protect the *Strelitzia* flowers from breaking off the inflorescence. The increased resistance to the destructive force of flowers can be related to the ability of silicon to connect to

Table 3. The influence of growth regulators on mechanical properties of *Strelitzia reginae* flowers

Conditioning 24 hours (A)	Storage 5 days (B)	Destruction maximum force (N)	Mean for A	Deformation at maximum force (mm)	Mean for A	Permanent damage energy (mJ)	Mean for A
H_2O (Control)	H_2O	7.7a	8.3A	3.6a	3.7A	18.0a	18.6A
	Chrysal	8.8a		3.8a		19.1a	–
Actisil	H_2O	8.1a	9.6B	3.9ab	4.3B	20.1a	25.7B
	Chrysal	11.0b		4.6b		31.2c	–
GA_3 + sucrose	H_2O	9.2ab	9.3AB	4.1ab	4.2B	23.7ab	25.2B
	Chrysal	9.4ab		4.3ab		27.5bc	–
Mean B	H_2O	8.3A		3.9A		20.6A	
	Chrysal	9.7B		4.2B		25.9B	

* Means followed by the same letter do not differ significantly at α = 0,05.

the cell wall elements, thereby producing a hard silicon-cellulose layer giving additional reinforcement along with the cuticle layer, hence the tissues gained additional resistance to mechanical damage [Babak and Majid 2011]. The increased mechanical strength of inflorescence stems was obtained after using silicon as foliar spraying by Zhao et al. [2013] on *Paeonia* shoots. The author noted that the silicon content in the inflorescence stem was significantly increased and it was distributed mainly in the cortex and xylem. Isa et al. [2010] found that silicon was present in tissues involved in the rigidity of plants. Resistance of shoots and flowers to mechanical damage is extremely important during transport and storage of plant material, although modern methods of flower packaging have been developed, including the use of cardboard boxes during the transport [Dias et al. 2013].

CONCLUSIONS

The vase life and quality of *Strelitzia reginae* flower shoots and flowers depend on the treatment after cutting. The size of the sepals and petals increases when inflorescence shoots are conditioned in 200 mg·dm^{-3} GA_3 + 10% sucrose or 0.2% Actisil. Conditioning of flower shoots in 0.2% Actisil and storing in 10% Chrysal increases the vase life by 2 days and increases the value of mechanical parameters of flowers, which translates into greater flexibility, lower brittleness, and thus the lower susceptibility to breaking.

REFERENCES

Arrom, L., Munné-Bosch, S. (2012). Sucrose accelerates flower opening and delays senescence through a hormonal effect in cut lily flowers. Plant Sci., 188–189, 41–47. https://doi.org/10.1016/j.plantsci.2012.02.012

Babak, J., Majid, R. (2011). Carnation flowers senescence as influenced by nickel, cobalt and silicon. J. Biol. Environ. Sci., 5(15), 147–152.

Balas, J., Coronado, P., Teixeira da Silva, J., Jayatilleke, M. (2006). Supporting post-harvest performance of cut-Flowers using fresh-flower-refreshments and other vase-water-additives. In: Teixeira da Silva J. (ed.). Floriculture, ornamental plants and plant biotechnology: advances and topical issues, vol. IV. Global Science Books, Isleworth, UK, 612–629.

Bayogan, E.R.V., Jaroenkit, T., Paull, R.E. (2008). Postharvest life of bird-of-paradise inflorescences. Postharv. Biol. Technol., 48(2), 259–263. https://doi.org/10.1016/j.postharvbio.2007.10.010

Chen, D.S. (2003). Preliminary studies on preservative of cut *Gerbera jamesonii*. J. Hanshan Teach. Coll., 24, 75–78.

Criley, R.A., Paull, R.E. (1993). Review: postharvest handling of bold tropical cut flowers *Anthurium*, *Alpinia purpurata, Heliconia* and *Strelitzia*. Acta Hortic., 337, 201–211. https://doi.org/10.17660/ActaHortic.1993.337.26

Dias, G.M., Queiroz, S.J., Sanches, J., Tombolato, A.F.C. (2013). Mechanical damage on bird-of-paradise (*Strelitzia reginae*) postharvest. Rev. Brasi. de Horticult. Ornament., 19(2), 93–98. https://doi.org/10.14295/rbho.v19i2.653

El-Saka, M., Awad, A.E., Fahmy, B., Dowh, A.K. (1995). Trials to improve the quality of *Strelitzia reginae* Ait. flowers after cutting. In: El-Otmani, M. (ed.). Postharvest physiology, pathology, and technologies for horticultural commodities: recent advances. Proceedings of an International Symposium, Agadir, Morocco, 480–488.

Finger, F.L., Campanha, M.M., Barbosa, J.G., Fontes, P.C.R. (1999). Influence of ethephon, silver thiosulfate and sucrose pulsing on bird-of-paradise vase life. Rev. Brasi. de Fisiol. Veg. 11, 119–122.

Finger, F.L., de Moraes, P.J., Barbosa, J.G., Grossi, J.A.S. (2003). Vase life of bird of paradise flowers influenced by pulsing and term of cold storage. Acta Hortic., 628, 863–867. https://doi.org/10.17660/ActaHortic.2003.628.110

Han, S.S. (2003). Role of sugar in the vase solution on postharvest flower and leaf quality of oriental Lily 'Stargazer. HortSci., 38(3), 412–416. http://dx.doi.org/10.21273/HORTSCI.38.3.412

Hassan, F.A.S. (2009). Influence of 8-hydroxyquinoline sulphate and sucrose treatments on the postharvest quality of cut flowers of *Strelitzia reginae* and *Hippeastrum vittatum.* Acta Agron. Hungar., 57(2), 165–174. https://doi.org/10.1556/AAgr.57.2009.2.8

Isa, M., Bai, S., Yokoyama, T., Ma, J.F., Ishibashi, Y., Yuasa, T., Iwaya-Inoue, M. 2010. Silicon enhances growth independent of silica deposition in a low-silica rice mutant, Isi1. Plant Soil 331(1), 361–375. https://doi.org/10.1007/s11104-009-0258-9

Jaroenkit, T., Paull R. (2003). Postharvest handling of heliconia, red ginger and bird-of-paradise. HortTech., 13(2), 259–266. https://doi.org/10.21273/HORTTECH.13.2.0259

Kamenidou, S., Cavins T.J., Marek S. (2008). Silicon supplements affect horticultural traits of greenhouse-produced ornamental sunflowers. HortSci., 43(1), 236–239. https://doi.org/10.21273/HORTSCI.43.1.236

Kamenidou, S., Cavins, T.J., Marek, S. (2010). Silicon supplements affect floricultural quality traits and elemental nutrient concentrations of greenhouse produced gerbera. Sci. Hortic., 123(3), 390–394. https://doi.org/10.1016/j.scienta.2009.09.008

Kazemi, M. (2012). Effect of cobalt, silicon, acetylsalicylic acid and sucrose as novel agents to improve vase-life of *Argyranthemum* flowers. Trends App. Sci. Res. 7(7), 579–583. https://dx.doi.org/10.17311/tasr.2012.579.583

Kazemi, M., Asadi, M., Aghdasi, S. (2012a). Postharvest life of cut lisianthus flowers as affected by silicon, malic acid and acetylsalicylic acid. Res. J. Soil. Biol. 4(1), 15–20. http://dx.doi.org/10.3923/rjsb.2012.15.20

Kazemi, M., Gholami, M., Asadi, M., Aghdasi, S. (2012b). Efficiency of silicon, nickel and acetylsalicylic acid reduced senescence and extended vase life of cut rose flowers. Trends App. Sci. Res., 7(7), 590–595. https://dx.doi.org/10.17311/tasr.2012.590.595

Kazemi, M., Gholami, M., Bahmanipour, F. (2012c). Effect of silicon and acetylsalicylic acid on antioxidant activity, membrane stability and ACC-oxidase activity in relations to vase life of carnation cut flowers. Biotech. 11(2), 87–90. http://dx.doi.org/10.3923/biotech.2012.87.90

Kew Species Profiles. Available: https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:798194-1 [date of access: 20.12.2021].

Koley, T., Gupta, Y., Sharma, P., Dhiman, S. (2017). Standardization of holding solution to enhance vase life and postharvest quality of cut stem of bird of paradise, *Strelitzia reginae* Ait. Int. J. Farm Sci. 7(4), 53–57. http://dx.doi.org/10.13140/RG.2.2.20055.98728

Krstulović, A., Prebeg, T., Mekinić, I. G., Dovedan, I. H., Gunjača, J. (2018). GA_{4+7} plus benzyladenine in combination with sucrose improves postharvest leaf and inflorescence quality in lilium 'Alma Ata'. Acta Sci. Pol. Hortorum Cultus 17(3), 29–40. https://doi.org/10.24326/asphc.2018.3.3

Onoda Y., Schieving, F., Anten, N.P.R. (2015). A novel method of measuring leaf epidermis and mesophyll stiffness shows the ubiquitous nature of the sandwich structure of leaf laminas in broad-leaved angiosperm species. J. Exp. Bot. 66(9), 2487–2499. https://doi.org/10.1093/jxb/erv024

Rabiza-Świder, J., Skutnik, E., Chodorowska, M. (2012). The effect of growth regulators and preservative on senescence of cut oriental lily 'Helvetia'. Acta Sci. Pol. Hortorum Cultus, 11(5), 183–194. https://doi.org/10.5586/aa.2014.038

Rabiza-Świder, J., Skutnik, E., Jędrzejuk, A., Łukaszewska, A., Lewandowska, K. (2015). The effect of Ga_3 and the standard preservative on keeping qualities of cut la hybrid lily 'Richmond'. Acta Sci. Pol. Hortorum Cultus, 14(4), 51–64.

Reinten, E.Y., Coetzee, J.H., van Wyk, B.-E. (2011). The potential of South African indigenous plants for the international cut flower trade. S. Afr. J. Bot., 77(4), 934–946. http://dx.doi.org/10.1016/j.sajb.2011.09.005

Sacała, E. (2009). Role of silicon in plant resistance to water stress. J. Elementol. 14(3), 619–630. http://dx.doi.org/10.5601/jelem.2009.14.3.20

Sajjad, Y., Jaskani, M.J., Asif, M., Qasim, M. (2017). Application of plant growth regulators in ornamental plants: a review. Pak. J. Agric. Sci. 54(2), 327–333. http://dx.doi.org/10.21162/PAKJAS/17.3659

Snyder, G.H., Martichenkov, V.V., Datnoff, L.E. (2007). Silicone. In: Barker, A.V., Pilibean, D.J. (eds.). Handbook of plant nutrition. CRC Taylor and Francis, New York, USA, 551–568.

Song, C.Y., Bang, C.S., Chung, S.K., Kim, Y.J., Lee, D.Ch., Lee, J.S. (1996). Effects of postharvest pretreatments and preservative solutions on vase life and flower quality of Asiatic hybrid Lily. Acta Hortic. 414, 277–285. https://doi.org/10.17660/ActaHortic.1996.414.34

Szot, P. (2010). Wpływ regulatorów wzrostu na jakość i trwałość pozbiorczą pędów kwiatowych tulipana. [The use of growth regulators on quality and postharvest storage of flower stems of tulips.]. Rozpr. Nauk. / Univ. Przyr. Lublin, 342, 76 [in Polish].

Whitted-Haag, B., Kopsell, D.E., Kopsell, D.A., Rhykerd, R.L. (2014). Foliar silicon and titanium applications influence growth and quality characteristics of annual bedding plants. Open Hortic. J., 7, 6–15. http://dx.doi.org/10.2174/1874840601407010006

Wraga, K., Dobrowolska, A. (2008). Effects of Actisil on flowering and decorative value of garden pansy belonging to fancy group. Folia Univ. Agric. Stetin. Agric. Alim. Pisc. Zootech., 264(7), 117–122.

Yeat, C.S., Szydlik, M., Łukaszewska, A.J. (2012). The effect of postharvest treatments on flower quality and vase life of cut *Alstroemeria* 'Dancing Queen'. J. Fruit Ornam. Plant Res., 20(2), 147–160. http://dx.doi.org/10.2478/v10290-012-0024-6

Zaidi, A., Khan, M.S., Ahmad, E., Saif, S., Rizvi, A., Shahib, M. (2016). Growth stimulation and management of diseases of ornamental plants using phosphate solubilizing microorganisms: current perspective. Acta Physiol. Plant. 38(5), 117. http://dx.doi.org/10.1007/s11738-016-2133-7

Zhao, D., Hao, Z., Tao, J., Han C. (2013). Silicon application enhances the mechanical strength of inflorescence stem in herbaceous peony (*Paeonia lactiflora* Pall.). Sci. Hortic., 151(28), 165–172.