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ASSESSMENT OF THE LONGEVITY AND WATER RELATIONS OF CUT GLADIOLUS 'WHITE PROSPERITY' IN RESPONSE TO GA_3 CORMS PRETREATMENT AND THE COMPOSITION OF THE HOLDING SOLUTION

Short communication

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ABSTRACT

The experiment was carried out in the Botanical Garden and Plant Physiology Laboratory, Department of Botany, Kurukshetra University (India) to identify the effect of postharvest treatments on qualitative traits of control (untreated) and GA_3 pretreated (100 ppm) corms of 'White Prosperity' gladiolus to enhance flower quality and prolong longevity. Different concentrations of sucrose alone and in combinations with citric acid and 8-hydroxyquinoline (8-HQ) [T_0 – control (DDW); T_1 – 8% sucrose; T_2 – sucrose (8%) + citric acid (200 ppm); T_3 – sucrose (8%) + 8-HQ (400 ppm); T_4 – citric acid (200 ppm); T_5 – sucrose (4%); T_6 – sucrose (4%) + citric acid (200 ppm); T_7 – sucrose (4%) + 8-HQ (400 ppm)] were used as postharvest treatments under completely randomized design with ten replicates per treatment. The moisture content and the fresh weight were higher in spikes obtained from GA_3 pretreated corms placed in sucrose (4%) + 8-HQ (400 ppm) solution as postharvest treatment followed by sucrose (4%) + citric acid (200 ppm) in gladiolus. The combination of sucrose (4%) + 8-HQ (400 ppm) followed by sucrose (4%) + citric acid (200 ppm) also demonstrated the best outcomes in terms of improving water uptake and vase life, which increased by ten days. These best preservative treatments are suitable for delaying flower senescence, prolonging the vase life, and enhancing the postharvest quality of gladioli. Further, this method can also help in testing new gladiolus hybrid selections.

Key words: 8-hydroxyquinoline, citric acid, fresh weight, water content, vase life

INTRODUCTION

Gladiolus L. (family: Iridaceae), also known as "sword lily" or "corn flag" is one of the most important bulbous flowering plants, which is known for its exquisite flower spikes that come in an array of captivating colors, forms, and sizes. It is commercially cultivated in western Asia, Africa, Eurasia, and Madagascar. It is used to create cut flowers, garden displays, and floral arrangements for interior design (Buschman 1990; Swaroop et al. 2018). Various cultural management techniques, such as appropriate planting material, spacing, temperature, humidity, light, irrigation, plant protection, harvesting, handling, etc., are necessary to improve the productivity and quality of any flower crop (Wani et al. 2023).

Gladioli propagate mainly by corms. Dormancy of the corms and cormels is a significant component that controls gladiolus growth and development. Three to five months of dormancy of corms due to the accumulation of growth-inhibiting substances, especially abscisic acid, limits their direct use in the following season and impairs year-round gladioli production (Kumar & Raju 2007).

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To design an efficient strategy to break the dormancy, technology related to chemical treatments for breaking dormancy needs to be disseminated to take up off-season production of gladioli (Wu et al. 2019).

Plant growth regulators (PGRs) are naturally biosynthesized chemicals in plants that have the potential to alter or control numerous biochemical and physiological processes, such as cell division, cell enlargement, flowering, fruiting, and seed formation, under unfavorable environmental conditions and to a noticeable degree when applied in moderate concentrations (Pal et al. 2016; Khan et al. 2024). Gibberellins are plant growth regulators that are known to improve key vegetative and floral traits in floricultural crops by inducing physiological responses in plants and changing the source-sink metabolism through their effect on photosynthesis and sink formation (Iqbal et al. 2011; Rani & Singh 2013; Pal et al. 2018a). It is well acknowledged that a balance between plant hormones interacting with one another and other internal elements controls numerous plant processes, including senescence (Halevy & Mayak 1981; Pal et al. 2018b; Thakur et al. 2023).

Flower senescence is a major issue that most ornamental plants face after growing and flowering (Shahri & Tahir 2011). In cut flowers, the common causes of decreased vase life are dehydration, low carbohydrate supply, ethylene, and other associated metabolic events (Nguyen & Lim 2021). Consequently, there is a reduction in the longevity of the flower stems and water absorption due to the loss of cell turgor pressure resulting from blockage of the xylem vessels by microbial contamination at the base of the stem (Shimizu-Yumoto & Ichimura 2010; Alaey et al. 2011; Mansouri 2012).

There are various chemical preservatives available to extend the vase life of flowers. These include sucrose, which provides energy, and citric acid, 8-HQ, to reduce pathogenic proliferation and prevent xylem occlusion. Thus, these preservatives assist consumers in improving the longevity of cut flowers for an extended period (Gupta & Dubey 2018).

With the practical implications of postharvest treatments in mind, the present study was carried out to compare the efficiency of sucrose alone and in combination with citric acid and 8-HQ on the quality and vase life of control (untreated) and GA_3 pretreated corms of 'White Prosperity' gladiolus.

MATERIALS AND METHODS

The investigation was conducted in open fields using a completely randomized block design at the Botanical Garden of Kurukshetra University, India. Healthy corms of 'White Prosperity' gladiolus (3 cm diameter) provided by the Indian Agricultural Research Institute (IARI), New Delhi, were used. Gladiolus corms were sown on raised beds (4.0 m × 4.0 m) in October and November for three consecutive years. The corms received a 12-hour dipping treatment with GA_3 (100 ppm) before planting, which proved to be best in enhancing yield attributes like corm and cormel production, as evident from our earlier research (Rani et al. 2015). Following treatment, every corm was removed and placed in a shaded area for two hours. Raised beds were used for the planting with 20–25 cm spacing between each corm. Plants were irrigated at regular intervals. Standard packages and practices were followed to raise the crop under field conditions.

During flowering, the spikes from the control and GA_3-treated corms were harvested. The spikes were cut with a sharp knife or scalpel in the early morning. To avoid cavitation, the spikes immediately transported to the laboratory. The lowermost couple of centimeters of the spikes were resliced underwater to a consistent length of 20 cm. Then, spikes were moved to the following holding solutions in the laboratory: T_0 – control (only DDW); T_1 – sucrose 8% (8 g in 100 ml DDW water); T_2 – sucrose 8% + citric acid 200 ppm; T_3 – sucrose 8% + 8-HQ 400 ppm (0.4 g in 1000 ml of DDW); T_4 – citric acid 200 ppm (0.2 g in 1000 ml double distilled water); T_5 – sucrose (4%); T_6 – sucrose (4%) + citric acid 200 ppm; T_7 – sucrose 4% + 8-HQ 400 ppm. For the experiment, 20 cm long spikes were selected in which only one or two lower florets were open. The spikes were all cleaned and placed singly in holding solutions in 200 ml Borosil conical flasks. Each experiment consisted of ten replicates per treatment. The entire experiment was set up at room temperature (13–28 ℃), with day and night intensity levels of 2.24 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and 1.13 $\mu mol \cdot m^{-2} \cdot s^{-1}$, respectively.

The longevity or vase life (in days), moisture content in petals (in %), volume of absorbed solution (in ml), and fresh weight of spikes (in g) were made at 0 (day of placement in holding solution), 3 and 6 days. Visible effects were recorded regularly through spikes' external appearance and freshness during postharvest life. The longevity of spikes were recorded in days from when they were placed in holding solutions and terminated when fifty percent of spike would undergo senescence. In a similar manner, the volume of holding solution absorbed by the spike in each flask was recorded. Initial moisture was assigned 100%. The moisture content in the petals was estimated as a percentage of the initial fresh weight using the following formula: moisture content (%) = (FMC × 100)/IMC, where FMC is the final petal weight on the days 3 and 6 and IMC is the initial petal weight on day zero. The fresh weight of spike (g) in each flask was recorded by weighing.

Each experiment consisted of ten replicates per treatment. The mean of the data for each block and each parameter was calculated. The collected data was analyzed by a completely randomized design using one-way analysis of variance (ANOVA). Multiple comparison test (LSD) was applied only for significant effect. Means were determined by the LSD test if significant F values were obtained at the 0.05% significance level. All statistical analyses were performed using SAS software (version 9.3, SAS Institute, USA). Duncan`s multiple range test (DMRT) was used to compare the mean differences at p = 0.05 on each significant variable measured.

RESULTS

Visible effect

The greatest wilting was observed in gladiolus spikes kept in DDW, both in untreated and GA_3-pretreated spikes, and the least wilting was observed in spikes produced from GA_3-pretreated corms kept in 4% sucrose combined with citric acid (200 ppm) and 8-HQ (400 ppm).

The volume of absorbed solution

Pretreatment of corms in GA_3 solution increased the volume of taken-holding solutions by about 5% (Table 1). Each modification of the holding solution gradually increased the amount taken from 70.5 ml to 120.8 ml (corms not pretreated) and from 78.3 ml to 125.4 ml (corms pretreated with GA_3. The most spectacular increase was at sucrose 4% + 8-HQ 400 ppm.

Vase life

The vase life of flowers was longer for spikes from corms treated with GA_3, regardless of the holding solution. The difference in the control kept in water was 0.8 days; for the best combination (sucrose 4% + 8-HQ) it was 1.9 days (Table 1). Sucrose (4%) + citric acid (200 ppm) as postharvest treatments showed the most significant increase.

Moisture content

Compared to subsequent days, the moisture content was highest on day 0. Moisture content dropped with time of maintenance. The maximum moisture reduction was noted in the control group (37% on day 6) that was not treated with GA_3 and 30% in the group treated. Spikes from GA_3 pretreated corms showed higher moisture content than untreated ones, regardless of the holding solution (Table 2). Spikes from pretreated and unpretreated GA_3 corms retained moisture best when kept in a solution with 4% sucrose and 8-HQ (92% and 80%, respectively). Slightly lower water loss was recorded using 4% sucrose and 8-HQ.

Fresh weight

Pre- and postharvest treatments increased the fresh weight, demonstrating their superiority over the control (Table 3). At day 3 of holding, all spikes from both GA_3-pretreated and untreated corms showed a slight increase in fresh weight, but at day 6, the fresh weight of spikes decreased. The lowest fresh weight loss was recorded in the group treated with GA_3 and maintained in 4% sucrose and 8-HQ or citric acid.

Table 1. Effect of pretreatment and postharvest treatments on the volume of absorbed holding solution (ml) on day 6 of by the spikes and the vase life of 'White Prosperity' gladiolus (initial volume = 200 ml, means ± SE, n = 10)

Corms treatment	Postharvest treatments	Volume of absorbed solution (ml)	Vase life (days)
Control (0 ppm)	T_0	70.5 ± 1.3^{g}	5.4 ± 0.32^{f}
	T_1	76.2 ± 0.8^{f}	6.2 ± 0.50^{e}
	T_2	77.2 ± 0.8^{ef}	7.0 ± 0.21^{d}
	T_3	77.4 ± 0.4^{e}	7.25 ± 0.26^{cd}
	T_4	85.3 ± 0.6^{d}	8.1 ± 0.15^{c}
	T_5	95.7 ± 0.8^{c}	8.4 ± 0.38^{c}
	T_6	100.6 ± 0.6^{b}	9.45 ± 0.32^{b}
	T_7	120.8 ± 0.4^{a}	10.84 ± 0.15^{a}
	F	190.8*	32.62*
	CD	0.876*	0.36*
	CV	1.644*	7.405*
GA_3 (100 ppm)	T_0	78.3 ± 1.3^{g}	6.15 ± 0.42^{ef}
	T_1	80.2 ± 0.4^{ef}	6.75 ± 0.47^{e}
	T_2	80.4 ± 0.7^{ef}	7.90 ± 0.54^{d}
	T_3	81.6 ± 0.5^{e}	8.24 ± 0.43^{Cd}
	T_4	90.4 ± 0.8^{d}	8.44 ± 0.12^{cd}
	T_5	101.5 ± 1.6^{c}	9.25 ± 1.04^{c}
	T_6	110.3 ± 0.7^{b}	10.83 ± 0.43^{b}
	T_7	125.4 ± 0.2^{a}	12.75 ± 0.46^{a}
	F	785.5*	55.643*
	CD	1.752 *	0.719*
	CV	1.644*	7.405*

Values within a column followed by the same letter are not significantly different according to Duncan's Multiple Range Test at the $P \leq 0.05$ level; T_0 – control (DDW); T_1 – 8% sucrose; T_2 – 8% sucrose + 200 ppm citric acid; T_3 – 8% sucrose + 400 ppm 8-Hydroxyquinoline; T_4 – 200 ppm citric acid; T_5 – 4% sucrose; T_6 – 4% sucrose + 200 ppm citric acid; T_7 – 4% sucrose + 400 ppm 8-Hydroxyquinoline; *CD* – critical difference value; *CV* – coefficient of variations

Table 2. Effect of pretreatment and postharvest treatments on moisture content (%) of petals in 'White Prosperity' gladiolus means ± SE, n = 10

Corms treatment	Postharvest treatments	Days after treatment		
		day 0	day 3	day 6
Control (0 ppm)	T_0	80.00 ± 0.13^{a}	68.40 ± 0.14^{gh}	50.50 ± 0.20^{f}
	T_1		69.00 ± 0.18^{g}	60.75 ± 0.16^{de}
	T_2		70.30 ± 0.16^{f}	61.60 ± 0.15^{d}
	T_3		72.40 ± 0.10^{e}	62.40 ± 0.15^{c}
	T_4		74.32 ± 0.14^{d}	62.85 ± 0.17^{bc}
	T_5		75.00 ± 0.10^{c}	63.80 ± 0.19^{b}
	T_6		77.20 ± 0.10^{b}	64.10 ± 0.18^{a}
	T_7		78.10 ± 0.19^{a}	64.40 ± 0.14^{a}
	F		38.15*	34.03*
	CV		3.951*	2.231*
	CD		0.557*	0.431*
GA_3 (100 ppm)	T_0	89.12 ± 0.17^{a}	79.32 ± 0.18^{h}	62.31 ± 0.17^{f}
	T_1		80.24 ± 0.18^{ef}	64.35 ± 0.15^{e}
	T_2		81.53 ± 0.15^{e}	75.41 ± 0.10^{d}
	T_3		83.16 ± 0.10^{d}	77.23 ± 0.19^{cd}
	T_4		85.37 ± 0.10^{c}	78.11 ± 0.18^{c}
	T_5		86.14 ± 0.10^{bc}	79.13 ± 0.18^{bc}
	T_6		87.22 ± 0.14^{b}	80.12 ± 0.19^{b}
	T_7		88.45 ± 0.15^{a}	82.12 ± 0.19^{a}
	F		87.476*	31.52*
	CV		1.836*	1.657*
	CD		0.618*	0.322*

Note: see Table 1

Table 3. Effect of pretreatment and postharvest treatments on fresh weight (g) of spikes in 'White Prosperity' gladiolus (initial volume = 200 ml; means ± SE, n = 10).

Corms treatment	Postharvest treatments	Days after treatment		
		day 0	day 3	day 6
Control (0 ppm)	T_0	53.61 ± 0.21^{a}	55.21 ± 0.56^{g}	40.36 ± 0.21^{gh}
	T_1		56.58 ± 0.45^{fg}	41.87 ± 0.22^{g}
	T_2		56.63 ± 0.76^{f}	45.98 ± 0.54^{f}
	T_3		58.88 ± 0.40^{e}	48.56 ± 0.43^{e}
	T_4		60.98 ± 0.53^{d}	53.75 ± 0.23^{d}
	T_5		62.62 ± 0.87^{c}	58.76 ± 0.12^{c}
	T_6		64.43 ± 0.86^{b}	62.44 ± 0.54^{b}
	T_7		66.88 ± 0.71^{a}	64.55 ± 0.45^{a}
	F	NA	34.03*	128.8*
	CD		0.496*	0.377*
	CV		2.231*	2.687*
GA_3 (100 ppm)	T_0	64.12 ± 0.43^{a}	65.32 ± 0.43^{h}	55.34 ± 0.65^{h}
	T_1		67.34 ± 0.45^{fg}	58.38 ± 0.23^{fg}
	T_2		68.27 ± 0.76^{ef}	59.22 ± 0.54^{f}
	T_3		69.23 ± 0.30^{e}	60.88 ± 0.23^{e}
	T_4		70.32 ± 0.46^{d}	76.43 ± 0.65^{d}
	T_5		71.45 ± 0.36^{c}	78.67 ± 0.44^{c}
	T_6		77.87 ± 0.56^{b}	80.32 ± 0.25^{b}
	T_7		81.65 ± 0.31^{a}	84.33 ± 0.45^{a}
	F	NA	87.11*	29.36*
	CD		0.518*	0.312*
	CV		1.424*	5.023*

Note: see Table 1

DISCUSSION

Our study showed that sucrose alone was very effective in preventing wilting and preserving the freshness of gladiolus spikes. It was also observed that sucrose performed even better when combined with 200 ppm of citric acid and 8-HQ (400 ppm) to control wilting.

The vase life of the cut gladiolus flowers was tightly connected with the amount of solution absorbed, the moisture content of petals, and the fresh weight of spikes. It was longer in the spikes grown from GA_3-treated corms over control. It agrees with the fresh weight of spikes observed on *Lathyrus odoratus* (Elhindi 2012). GA_3 slowed the onset of leaf senescence by up to 7 days and the fall of petals by two days in *Alstroemeria* cut flowers (Mutui et al. 2006). It may be because untreated flowers have a limited capacity to absorb water and an imbalance between transpiration and uptake, resulting in an unrecoverable senescence (Verdonk et al. 2023). According to Elhindi (2012), sucrose enhances the body's capacity to absorb water and maintain turgidity, making it an excellent respiratory substrate and energy source for maintaining osmotic potential. The highest moisture content, fresh weight, and vase life of cut spikes may result from GA_3's potential to raise the sugar content in gladiolus leaves. At the same time, 8-HQ's ability to inhibit microbial growth may cause an increasing amount of solution absorption.

Since cut flowers are susceptible to oxidative stress and desiccation during their vase life, GA_3 may control spike petals' membrane integrity and antioxidative activity under stress (Varu & Barad 2007). Thus, several retentive treatments were employed in the current study to extend the flower's postharvest lifetime. Citric acid and 8-HQ function as effective biocide because they reduce the pH of the vase solution and impede the growth of bacteria in xylem vessels, which helps in water uptake. GA_3 application, along with sucrose (4%), citric acid, and 8-HQ, increased in our experiment the photosynthetic rate by enhancing chlorophyll content and leaf area and accumulating a more significant amount of assimilates for the growth of spikes with increased length (data not given). Sucrose alone proved most promising in delaying shrinkage and decrease in Chrysanthemum (Liu et al. 2023). In the case of *Iris germanica* and *Iris kashmiriana*, the combination of NAA with sucrose had a deleterious effect on the vase life and promoted premature senescence (Sultan & Farooq 1998). Carbohydrates, mainly sucrose, are an essential source of energy for plant tissues (Sumaryono 2012). The fresh weight of spikes was significantly affected by GA_3 and sucrose because of the energy source and ingestion of the vase solution. It has also been proposed that GA_3 and sucrose could increase the fresh weight of cut flowers of gladiolus and *Dianthus caryophyllus* (Mishra & Khanal 2019; Punitha et al. 2023).

After three days, the fresh weight may have reduced due to increased water loss or lower water intake and a fall in the membrane stability index. Other researchers also observed the similarity of fresh weight loss in Bougainvillea, daylilies, and roses throughout senescence (Singh et al. 2007; Moneruzzaman et al. 2010; Horibe & Yamada 2017). It was shown that by lowering vascular obstruction and eventually fresh weight, compounds used to extend vase life increased the water absorption and moisture content of spikes. Many cut flowers now require biocides combined with sugars as a preservative (Pun & Ichimura 2003). Treating flowers with antimicrobial agents inhibits the reduction of hydraulic conductivity and prevents the growth of germs (Van Doorn et al. 1990; De Witte et al. 2014; Jafarpour et al. 2015). 8-Hydroxyquinovase and line-5-sulfonic acid (HQS) extended the rose's fresh weight and vase life. However, this treatment became much more successful when sucrose was added to HQS, which caused Antirrhinum majus to have the most extended vase life (Asrar 2012). Anti-microbial qualities of the 8-HQ have been shown to remove vascular obstruction and improve water absorption in cut flowers (Burdett 1970; Ali & Hassan 2014). GA_3 and biocides work together to minimize membrane permeability by protecting protein phospholipids from peroxidation, leading to reduced membrane leakage (Singh et al. 2008; Mishra & Khanal 2019).

CONCLUSIONS

Dipping gladiolus corms in water solution of GA_3 100 ppm before planting increases the quality of cut flowers. Further, the holding solution containing sucrose (4%) + 8-HQ (400 ppm) or sucrose (4%) + citric acid (200 ppm) increases preservation of the fresh weight of cut gladiolus spikes and moisture content of petals. The above treatments can double the vase life of cut gladioli up to 12 days.

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REFERENCES

Alaey M., Babalar M., Naderi R., Kafi M. 2011. Effect of pre- and postharvest salicylic acid treatment on physio-chemical attributes in relation to vase-life of rose cut flowers. Postharvest Biology and Technology 61(1): 91–94. DOI: 10.1016/j.postharvbio.2011.02.002.

Ali E., Hassan F. 2014. Postharvest quality of *Strelitzia reginae* Ait. cut flowers in relation to 8-hydroxyquinoline sulphate and gibberellic acid treatments. Scientia Agriculturae 5(3): 97–102. DOI: 10.15192/pscp.sa.2014.1.3.97102.

Asrar A.-W.A. 2012. Effects of some preservative solutions on vase life and keeping quality of snapdragon (*Antirrhinum majus* L.) cut flowers. Journal of the Saudi Society of Agricultural Sciences 11(1): 29–35. DOI: 10.1016/j.jssas.2011.06.002.

Burdett A.N. 1970. The cause of bent neck in cut roses. Journal of the American Society for Horticultural Science 95(4): 427–431. DOI: 10.21273/jashs.95.4.427.

Buschman J.C.M. 1990. Gladiolus as cutflower in subtropical and tropical regions. International Flowerbulb Centre, the Netherlands, 31 p.

De Witte Y., Harkema H., Van Doorn W.G. 2014. Effect of antimicrobial compounds on cut *Gerbera* flowers: Poor relation between stem bending and numbers of bacteria in the vase water. Postharvest Biology and Technology 91: 78–83. DOI: 10.1016/j.postharvbio.2013.12.018.

Elhindi K.M. 2012. Evaluation of several holding solutions for prolonging vase-life and keeping quality of cut sweet pea flowers (*Lathyrus odoratus* L.). Saudi Journal of Biological Sciences 19(2): 195–202. DOI: 10.1016/j.sjbs.2011.12.001.

Gupta J., Dubey R.K. 2018. Factors affecting post-harvest life of flower crops. International Journal of Current Microbiology and Applied Science 7(1): 548–557. DOI: 10.20546/ijcmas.2018.701.065.

Halevy A.H., Mayak S. 1981. Senescence and post-harvest physiology of cut flowers – Part 2. Horticultural Reviews 3: 59–143. DOI: 10.1002/9781118060766.ch3.

Horibe T., Yamada K. 2017. Petal growth physiology of cut rose flowers: progress and future prospects. Journal of Horticultural Research 25(1): 5–18. DOI: 10.1515/johr-2017-0001.

Iqbal N., Nazar R., Khan M.I.R., Masood A., Khan N.A. 2011. Role of gibberellins in regulation of source–sink relations under optimal and limiting environmental conditions. Current Science 100(7): 998–1007.

Jafarpour M., Golparvar A.R., Askari-Khorasgani O., Amini S. 2015. Improving postharvest vase-life and quality of cut gerbera flowers using natural and chemical preservatives. Journal of Central European Agriculture 16(2): 199–211. DOI: 10.5513/jcea01/16.2.1610.

Khan S., Singh R., Kaur H., Kumar A., Vashishth A., Shahwan M., Tuli H.S. 2024. Plant growth regulator-mediated response under abiotic stress: A review. Journal of Applied Biology and Biotechnology 12(2): 13–21. DOI: 10.7324/jabb.2024.157299.

Kumar P.N., Raju D.V.S. 2007. Dormancy in gladiolus: the cause and remedy – A review. Agricultural Reviews 28(4): 309–312.

Liu X.-F., Teng R., Xiang L., Li F., Chen K. 2023. Sucrose-delaying flower color fading associated with delaying anthocyanin accumulation decrease in cut chrysanthemum. PeerJ 11; e16520; 13 p. DOI: 10.7717/peerj.16520.

Mansouri H. 2012. Salicylic acid and sodium nitroprusside improve postharvest life of chrysanthemums. Scientia Horticulturae 145: 29–33. DOI: 10.1016/j.scienta.2012.07.016.

Mishra P., Khanal A. 2019. Vaselife analysis of gladiolus using different vase solutions. Journal of Bioscience and Agriculture Research 21(1): 1749–1754. DOI: 10.18801/jbar.210119.213.

Moneruzzaman K.M., Hossain A.B.M.S., Amru N.B., Saifudin M., Imdadul H., Wirakarnain S. 2010. Effect of sucrose and kinetin on the quality and vase life of *Bougainvillea glabra* var. Elizabeth Angus bracts at different temperatures. Australian Journal of Crop Science 4(7): 474–479.

Mutui T.M., Emongor V.E., Hutchinson M.J. 2006. The effect of gibberellin$_{4+7}$ on the vase life and quality of *Alstroemeria* cut flowers. Plant Growth Regulation 48(3): 207–214. DOI: 10.1007/s10725-006-0014-6.

Nguyen T.K., Lim J.H. 2021. Do eco-friendly floral preservative solutions prolong vase life better than chemical solutions? Horticulturae 7(10); 415; 11 p. DOI: 10.3390/horticulturae7100415.

Pal P., Yadav K., Kumar K., Singh N. 2016. Effect of gibberellic acid and potassium foliar sprays on productivity and physiological and biochemical parameters of parthenocarpic cucumber cv. 'Seven Star F_1'. Journal of Horticultural Research 24(1): 93–100. DOI: 10.1515/johr-2016-0011.

Pal P., Yadav K., Kumar K., Singh N. 2018a. Efficacy of foliar application of GA_3 and K on growth and biochemical parameters of two F_1 hybrid parthenocarpic cultivars of cucumber. Journal of Horticultural Research 26(2): 5–13. DOI: 10.2478/johr-2018-0011.

Pal P., Yadav K., Kumar K., Singh N. 2018b. Multifaceted potential of K and GA_3 on growth, production and quality of F_1 hybrid *Cucumis sativus* L. (cv. KUK-9). Acta Scientiarum Polonorum, Hortorum Cultus 17(1): 127–138. DOI: 10.24326/asphc.2018.1.12.

Pun U.K., Ichimura K. 2003. Role of sugars in senescence and biosynthesis of ethylene in cut flowers. Japan Agricultural Research Quarterly 37(4): 219–224. DOI: 10.6090/jarq.37.219.

Punitha A., Sumathi T., Uma Sankareswari R., Geethalakshmi I., Adeline Vinila J.E., Subha L. 2023. Post-harvest life of cut carnation (*Dianthus caryophyllus* L. cv. Malaga) as influenced by holding solutions. Pharma Innovation 12(6): 313–316.

Rani P., Singh N. 2013. Impact of gibberellic acid pretreatment on growth and flowering of tuberose (*Polianthes tuberosa* L.) cv. Prajwal. Journal of Tropical Plant Physiology 5: 33–42.

Rani P., Yadav K., Kataria N., Singh N., Dar M.H., Groach R. 2015. Assessment of growth, floral and yield attributes of gladiolus in response to gibberellic acid treatment. Botany Research International 8(1): 1–6. DOI: 10.5829/idosi.bri.2015.8.1.84197.

Shahri W., Tahir I. 2011. Flower senescence-strategies and some associated events. Botanical Review 77(2): 152–184. DOI: 10.1007/s12229-011-9063-2.

Shimizu-Yumoto H., Ichimura K. 2010. Combination pulse treatment of 1-naphthaleneacetic acid and aminoethoxyvinylglycine greatly improves postharvest life in cut *Eustoma* flowers. Postharvest Biology and Technology 56(1): 104–107. DOI: 10.1016/j.postharvbio.2009.10.001.

Singh A., Kumar J., Kumar P., Singh V.P. 2007. Membrane stability and post harvest keeping quality of gladiolus cut spikes as influenced by certain chemicals with sucrose in vase solution. Indian Journal of Plant Physiology 12(1): 63–71.

Singh A., Kumar J., Kumar P. 2008. Effects of plant growth regulators and sucrose on post harvest physiology, membrane stability and vase life of cut spikes of gladiolus. Plant Growth Regulation 55(3): 221–229. DOI: 10.1007/s10725-008-9278-3.

Sultan M., Farooq S. 1998. The keeping quality of *Iris* L. (I) – Effect of sucrose, NAA, GA_3 and cobalt chloride on flower bud development and vase life. Progressive Horticulture 30(1–2): 1–7.

Sumaryono, Muslihatin W., Ratnadewi D. 2012. Effect of carbohydrate source on growth and performance of *in vitro* sago palm (*Metroxylon sagu* Rottb.) plantlets. HAYATI Journal of Biosciences 19(2): 88–92. DOI: 10.4308/hjb.19.2.88.

Swaroop K., Singh K.P., Kumar P., Sindhu S.S. 2018. Improvement and performance of gladiolus hybrids for flower traits/novel colour and higher corm multiplication. International Journal of Agriculture Innovations and Research 6(4): 4–7.

Thakur R., Thakur R., Chandermohan N.C., Kanwar B. 2023. Effect of gibberellic acid and benzyl adenine on ornamental plants: A review. Pharma Innovation 12(2): 101–105. DOI: 10.22271/tpi.2023.v12.i2b.18710.

Van Doorn W.G., De Witte Y., Perik R.R.J. 1990. Effect of antimicrobial compounds on the number of bacteria in stems of cut rose flowers. Journal of Applied Bacteriology 68(2): 117–122. DOI: 10.1111/j.1365-2672.1990.tb02555.x.

Varu D.K., Barad A.V. 2007. Effect of date of harvest and floral preservatives on vase life of cut flowers in tuberose (*Polyanthes tuberosa* L.) cv. Double. Journal of Horticultural Sciences 2(2): 148–152. DOI: 10.24154/jhs.v2i2.624.

Verdonk J.C., Van Ieperen W., Carvalho D.R.A., Van Geest G., Schouten R.E. 2023. Effect of preharvest conditions on cut-flower quality. Frontiers in Plant Science 14; 1281456; 8 p. DOI: 10.3389/fpls.2023.1281456.

Wani M.A., Din A., Nazki I.T., Rehman T.U., Al-Khayri J.M., Jain S.M. et al. 2023. Navigating the future: exploring technological advancements and emerging trends in the sustainable ornamental industry. Frontiers in Environmental Science 11; 1188643; 22 p. DOI: 10.3389/fenvs.2023.1188643.

Wu J., Jin Y., Liu C., Vonapartis E., Liang J., Wu W. et al. 2019. GhNAC83 inhibits corm dormancy release by regulating ABA signaling and cytokinin biosynthesis in *Gladiolus hybridus*. Journal of Experimental Botany 70(4): 1221–1237. DOI: 10.1093/jxb/ery428.