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EVALUATION OF DIFFERENT PRESERVATIVE SOLUTIONS AND PACKAGING MATERIAL FOR IMPROVING POST HARVEST QUALITY OF GLADIOLUS (*Gladiolus grandiflorus*) CUT SPIKES

[a] Ayesha Manzoor *, Adnan-ur-Rahman [b] , Maryam Qamar [a], Sharmin Ashraf [a]

[a] Barani Agricultural Research Institute, Chakwal, Pakistan

[b] Big Birds Foods Private Limited, Lahore, Pakistan

*Corresponding email address: manzoorayesha12@yahoo.com

ABSTRACT

Gladiolus is an important cut flower in the world, and its preference in Pakistan is next to roses. But the main problem that occurs in gladiolus is that it has short vase life. The present experiment was conducted with an objective to investigate the effect of four preservative solutions [distilled water, Sucrose (3%), $AgNO_3$ (250 ppm), $AgNO_3$ (250 ppm) + Sucrose (3%)] and packaging material on postharvest quality of three gladiolus varieties, "Tissue, White Prosperity and Alexandra". Packaging material consists of control treatment (without packaging), packaging of cut spikes with 100 ppm acetic acid soaked cotton and packaging of polyethylene sheet after sucrose pulsing. The experiment was arranged as two factorial laid out according to completely randomized design (CRD) having three replications. Results showed that preservative solution having combination of $AgNO_3$ (250 ppm) + Sucrose (3%) significantly improves days to open basal floret, floret opening percentage (%), bloom spread (inch), floret length (inch), floret diameter (inch), fresh spike weight (g), dry spike weight (g), fresh weight loss (%) and vase life (days). Moreover, this treatment was also effective in reducing the wilting (%) in all gladiolus varieties. However, for solution uptake (mL/spike) and solution balance (ml/spike), $AgNO_3$ (250 ppm) alone gives the best results. For packaging treatment, the pulsing of a cut spike with 20% sucrose followed by polyethylene sheet wrapping proves to be effective. Among the varieties, Alexandra performed better for all quality parameters in comparison to White Prosperity and Tissue.

Key word: AgNO3, cut spike, gladiolus, polyethylene, postharvest, sucrose, vase life.

INTRODUCTION

Gladiolus (*Gladiolus grandiflorus* L.) a herbaceous bulbous plant, is one of the most important and common ornamental crops that is commercially cultivated worldwide. Gladiolus has known as "Sword lily" belongs to the family Iridaceace and is native to South Africa, Madagascar, Tropical Africa and Eurasia. It is also known as the "Queen of the Bulbous Flowers" cultivated due to its long gorgeous spikes with various shape, color (except true blue color) and size of floret (Shaukat *et al.*, 2013). It is widely used as a cut flower, ornamental plant for making indoor decorations, flower arrangements and bouquet (Vasanthakumar *et al.*, 2015).

In Pakistan, gladiolus ranks in 2nd numbers after the rose and cultivated on approximately more than 2000 hectare area. It is widely grown in Lahore, Islamabad, Rawalpindi, Jhang, Faisalabad, Sheikhupura, Okara, Patoki, Multan, Kasur, Rahim yar khan, Bahawalpur, Hyderabad, Swat, Mansera, Abbottabad and Dir region to use both as a potted plant and as a cut flower (Ali *et al.*, 2014). The cultivation of gladiolus has been increasing day by day among the farmers due to suitability to different agro-climatic conditions, increase awareness, easy cultural practices and high return or profit on investment (Riaz *et al.*, 2007). But the problem is that the cut flower of gladiolus is not long lasting (Mar *et al.*, 2011). The individual floret lasts for about 4 to 6 days and florets at the bottom of the spike senescence first while the above florets open and senescence successively (Yamada *et al.*, 2003). Although gladiolus is an ethylene insensitive plant still oxidative stress is one of the main factors involved in flower senescence (Ahmed *et al.*, 2018). Moreover, protocols related to its post-harvest handling are still not standardized, which results in a reduction of its vase life. Improper handling, non-availability of cold storage, geotropism phenomena, lack of standard preservative solutions or use of poor quality water to hydrate the freshly cut spikes are the factor that causes a reduction in longevity of vase life (Saleem *et al.*, 2014).

Cut flowers are living tissues having high metabolic activity, thus flower that separated from the mother plant senescence more quickly as due to a disturbance in the flow of water and nutrients from root to the flower parts (Sharma and Sarkar, 2018). Approximately there are 20% postharvest losses in cut flowers due to injury caused by insects, disease or physical damage during postharvest practices (Da Silva, 2003). The short vase life of cut flowers reduces cut flower marketability and consumer satisfaction. The limited postharvest life depends upon many factors such as a low internal concentration of sucrose, high ethylene production rate, microorganism growth, and adverse water relation. Interruption in water relation occurs due to vascular blockage by microbes or air at the cut end of the flower stem. Moreover, the disturbance in water balance may have led to several other physiological disorders like peduncle bending, prevention of flower bud opening and wilting of leaves and flowers that ultimately affect the vase life (Ha *et al.*, 2017).

In the past, cut flowers usually dipped in water after harvesting but as time goes on the use of the preservative solution is the most common practice done to prolong the vase life of cut flowers (Tariq *et al.*, 2017). Various types of preservatives like an energy source, ethylene absorbent, and germicides are used to enhance and improve the vase life of cut flowers (Awasthi *et al.*, 2013). Depending upon their application time and the concentration used, preservative solution has divided into three different classes i.e. bud opening solution, pulsing solution, and vase solution. The main elements of the preservative solution are sugar, water, and biocides. Moreover, growth regulators, acidifying agents, mineral nutrients and anti-ethylene compounds also added in floral preservative solutions (Tiwari *et al.*, 2010). Sugar in preservative solutions supplies food for respiration, whereas germicides like silver nanoparticles, hydroxyquinoline sulfate and chlorine help to limit bacterial growth and prevent the blockage of conducting tissues. Various types of sugars added to the preservative solution in order to prolong the vase life however the most commonly used sugar is sucrose. Cut flowers that harvest at bud stage, sucrose not only provides them with food for respiration but also supplies energy to open the flower buds (Asrar, 2012). Previously several chemicals such as citric acid, ascorbic acid, silver nitrate, aluminium sulphate, boric acid, 8-HQS, and cobalt sulphate were used alone or in combination with other components to improve vase life of gladiolus (Dwivedi *et al.*, 2018).

Although various post-harvest techniques like grading, sorting, pre-cooling and pulsing have a major part in improving the vase life of cut flowers, the proper packaging is most important practice employed to keep the cut flower in fresh form without losing their quality until they reach their final destination. As flowers are highly perishable and delicate thus external environment and water loss during transportation are harmful to cut flowers. The main objective of packaging is to lower respiration rate, transpiration, cell division and ethylene emission during transportation and long-term storage (Prashanth and Chandrasekar, 2010). Different packaging materials like polyethylene sheet, butter paper, corrugated cardboard boxes, aluminum lamination foil, craft paper, polypropylene sheet, fluted cardboard paper and cellophane paper are used for vase life extension (Gupta and Dubey, 2018). At room temperature pretreated flowers packed in both paraffin and polyethylene sheet proved effective then cellophane paper whereas, at 4^{o}C, polyethylene paper alone performed better than cellophane and paraffin (Farooq *et al.*, 2004).

OBJECTIVES

Thus keeping in view the economic importance of gladiolus in the country, the present research was conducted with an aim to enhance the cut flower vase life and quality through different preservative solutions and packaging material.

MATERIAL AND METHODS

Experimental site and plant material: The experiment was conducted during April-May, 2017. The room temperature and relative humidity of the laboratory during the experiment was about 24-28 ^{o}C and 60-70 % relative humidity with good air circulation. White light fluorescent tubes were used for illumination which lighted 10 hr per day. For research, fresh gladiolus spikes of "Tissue, White Prosperity and Alexandra" at tight bud stage purchased from commercial growers and transported immediately to the Plant Pathology Lab and placed them in water to avoid wilting. In the laboratory, fresh slanting cuts were made to cut spikes and fresh weight was recorded for each spike. After recording their fresh weight, spikes were placed in their respective solutions.

This trial was laid out in completely randomized design (CRD) having 3 replications per treatment. Data were analyzed by using two-way analysis of variance (ANOVA) through "Statistix 8.1"software and difference between means were compared by using the least significant difference (LSD) at 5% probability (Bulmer, 1979)

Treatments: In order to improve the vase life of cut gladiolus, the experiment was divided into two parts. In the first part, 4 different treatments of preservative solution were carried out on all three varieties such as Distilled water (control), Sucrose (3%), $AgNO_3$ (250 ppm) and $AgNO_3$ (250 ppm) + Sucrose (3%). Cut flower spikes were placed in glass bottles (250 mL) containing 200 mL preservative solution (Figure 1).

Figure 1: Gladiolus floral spikes placed in different preservative solutions.

In another part, different packaging materials were used to study their effect on vase life at room temperature. For this purpose, control treatment flowers were not packed or covered. In the second treatment, first the base of the flower spikes was covered with cotton and then these cotton covered spikes were dipped in a 100 ppm acetic solution. After that these cut spikes were placed in empty jam bottles in a standing position. In the third treatment, flowers were first placed in 1000 ppm solution of $AgNO_3$ for 10 minutes followed by pulsing for 18 hours (2pm- 8am) with 20% sucrose solution. After pulsing, the flower stem base wrapped with a polyethylene sheet and kept the flowers at a vertical position at room temperature.

Data collection: Data were collected on a daily basis to evaluate the quality of floral spikes in response to different preservative treatments. Parameters recorded were time taken to open basal floret (days), floret opening percentage (%), bloom spread [circumference] (inch), floral diameter (inch), floral length (inch), fresh spike weight (g), dry spike weight (g), total solution uptake (mL/spike), solution balance (mL/spike), fresh weight loss (%), vase life (days) and wilting (%) respectively. For packaging treatment, parameters recorded were vase life (days) and wilting (%).

RESULTS

Influence of different preservative solutions on quality parameters of gladiolus cut spike is summarized in Table 1. According to the results, significant variation was recorded for days taken to open basal floret among gladiolus varieties under four different preservatives. Minimum (average 4.7) days required to open basal floret was observed in "Tissue" when its spike was held in preservation solution of $AgNO_3$ (250 ppm) + Sucrose (3%) whereas "Alexandra" spike treated with distilled water need more days (average 10.3) to open basal floret. Analysis of results showed that gladiolus variety "Alexandra" spike had maximum floret opening percentage (29.8%) when it was placed in a preservative solution containing $AgNO_3$ (250 ppm) + Sucrose (3%) whereas the minimum number of florets opened (11%) in a variety "White Prosperity" when its cut spike was kept in distilled water. Largest floret bloom (15.9 inch) was examined in "Alexandra" under $AgNO_3$ (250 ppm) + Sucrose (3%) treatment. But control treatment (distilled water) resulted in minimum bloom spread (9.0 inch) in "Tissue". Similar to bloom spread parameter, floret diameter (5.0 in) and length (4.7 in) were also maximum in variety "Alexandra" when its spike was dipped in a preservative solution of $AgNO_3$ (250 ppm) + Sucrose (3%) whereas minimum floret diameter was recorded in "Tissue" when treated with distilled water (2.9 in). However, floret length in "Tissue" was not only shortest in distilled water treatment (2.6 in) but also in sucrose treatment (2.7 in). Data related to fresh spike weight of floral spikes revealed that in "Alexandra" variety, except control, all different treatments were significantly same and had maximum fresh spike weight that ranged from 99.3-101.2 g while on the other hand minimum fresh spike weight was examined in variety "Tissue" irrespective of the preservative solution used and it ranged from 49.8-52.7 g. Just like fresh weight, maximum dry spike weight (25.6 g) was recorded in "Alexandra" under $AgNO_3$ (250 ppm) + Sucrose (3%) treatment and minimum dry spike weight (4.6 g) was recorded in "Tissue" when its spike was placed in distilled water.

Under $AgNO_3$ (250 ppm) treatment, "Alexandra" variety uptake maximum amount of total preservative solution (377.3 mL/spike) while lowest amount of total solution uptake was recorded in variety "White Prosperity" (93.3 ml) in sucrose (3%) solution. The preservative solution containing $AgNO_3$ (250 ppm) was effective in maintaining maximum solution balance (245.7 ml/spike) in "Alexandra" but treatment with sucrose (3%) causes minimum water balance (104.3 g) in cut spikes of "Tissue". Distilled water, $AgNO_3$ (250 ppm) alone and in combination with sucrose [$AgNO_3$ (250 ppm) + Sucrose (3%)] causes a highest fresh weight loss (92%, 91.3% and 93.3%) in variety "White Prosperity". However lowest fresh weight loss (74.7%) was observed in variety "Tissue" under treatment having sucrose (3%). Data portrayed that maximum wilting percentage was recorded in "Alexandra" under control (43.3%) and sucrose (3%) treatment (42.7%). Moreover, variety "White Prosperity" florets wilted at a maximum rate (43%) when its spike was kept continuously in sucrose (3%) solution. The preservative solution having a composition of $AgNO_3$ (250 ppm) + Sucrose (3%) resulted in minimum floret wilting (33%) in variety "White Prosperity". The present study examined that a combination of $AgNO_3$ (250 ppm) with sucrose (3%) had a significant effect on the postharvest life of gladiolus spikes. It enhances the vase life of cut spikes up to 10 days in variety "Alexandra" as compared to distilled water treatment that prolonged the vase life in "Tissue" for only up to 5 days.

The improvement of the vase life of gladiolus varieties under different packaging material is presented in Figure 2.

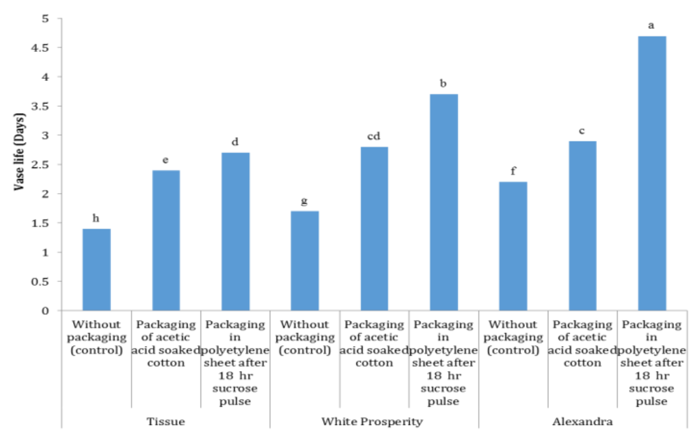

Figure 2: Impact of packaging material on vase life of gladiolus cut spikes

Wrapping of gladiolus spikes basal end with polyethylene sheet after pulsing with sucrose for 18 hr results in enhancement of vase life in all three varieties. However among varieties, "Alexandra" had maximum vase life (4.7 days). Variety "Tissue" floral spikes not packed with any other

Table1: Effect of different preservative solutions on postharvest quality of gladiolus cut spikes

Varieties	Treatment	DBF (days)	FOP (%)	BS (inch)	FD (in)	FL (in)	FSW (g)	DSW (g)	TSU (ml/spike)	SB (ml/spike)	FWL (%)	VS (days)	WP (%)
Tissue	Distilled water (control)	7.0 bcde	15.5 i	9.0 f	2.9 f	2.6 h	49.8 d	4.6 g	202.3 cd	168 cd	83.7 abc	5.3 e	41.7 ab
	Sucrose (3%)	6.7 cde	19.3 g	10.6 ef	3.4 ef	2.7 h	50.0 d	5.9 fg	145.3 ef	104.3 g	74.7 c	6.3 de	39.3 ab
	AgNO3 (250 ppm)	5.3 de	22.2 e	10.9 ef	3.5 ef	3.2 g	51.4 d	6.7 f	196.7 d	154.3 de	81.3 abc	7.0 cde	40.7 ab
	AgNO3 (250 ppm) + Sucrose (3%)	4.7 e	22.4 e	11.4 de	3.6 de	3.5 f	52.7 d	6.8 f	189.3 d	183.7 c	78.7 abc	7.3 bcde	36 ab
White Prosperity	Distilled water (control)	8.3 abc	11.0 j	11.2 e	3.6 e	3.9 e	65.5 c	10.4 e	125.2 fg	162 cd	92 a	6.7 de	41.3 ab
	Sucrose (3%)	7.7 abcd	18.6 h	12.1 cde	3.9 cde	4.2 cde	65.7 c	10.7 e	93.3 g	154 de	91.3 ab	8 abcd	43 a
	AgNO3 (250 ppm)	5.0 de	20.6 f	13.2 bcd	4.2 bcd	4.3 bcd	66.7 c	11.5 e	208 cd	149.3 def	93.3 a	8.3 abcd	33.3 ab
	AgNO3 (250 ppm) + Sucrose (3%)	7.7 abcd	24.9 b	14.9 ab	4.6 ab	4.4 abc	69.6 c	12.9 d	177 de	128.3 fg	91.7 a	8.7 abcd	33.0 b
Alexandra	Distilled water (control)	10.3 a	19.1 g	13.7 bc	4.4 bc	4.3 bcd	88.9 b	15.6 c	237.7 c	158.7 d	83.7 abc	8.7 abcd	43.3 a
	Sucrose (3%)	9.7 ab	23.3 d	13.9 abc	4.6 abc	4.2 de	99.3 a	16.8 bc	206.3 cd	130 ef	75.33 bc	9.3 abc	42.7 a
	AgNO3 (250 ppm)	8.3 abc	24.0 c	14.4 ab	4.6 ab	4.5 ab	100.7 a	17.5 b	377.3 a	245.7 a	85.7 abc	9.7 ab	36 ab
	AgNO3 (250 ppm) + Sucrose (3%)	8.3 abc	29.8 a	15.9 a	5.0 a	4.7 a	101.2 a	25.6 a	287.7 b	213.7 b	82.7 abc	10 a	35.3 ab

DBF= Days taken to open basal floret, FOP= Floret opening percentage, BS= Bloom spread, FD= Floret diameter, FL= Floret length, FSW= Fresh spike weight, DSW= Dry spike weight, TSU= Total solution uptake, SB= Solution balance, FWL= Fresh weight loss, W= Wilting, VS= Vase life, in= inch.

material had minimum vase life (1.4 days). As vase life and a wilting percentage is inversely co-related with other thus enhanced shelf life of "Alexandra" variety in polyethylene sheet wrapping can lead to a lowest wilting percentage (19.3%) (Figure 3). Floral spikes of all varieties that were remained uncovered as control treatment had a maximum wilting percentage but "White Prosperity" and "Tissue" had the highest wilting percentage (50.7 and 50.3%).

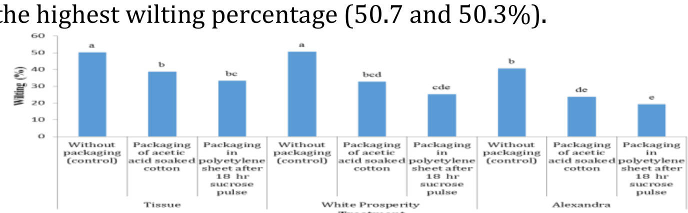

Figure 3: Impact of packaging material on wilting (%) of gladiolus cut spikes

DISCUSSION

Present research showed that the presence of sucrose (3%) and silver nitrate (250 ppm) in preservative solution causes an increase in vase life in all gladiolus cultivars. This may be due to the role of sucrose as an energy source by enhancing respiratory substrate mobilization and utilization (Hussen and Yassin, 2013) and behave as an osmotically active molecule that balance the water relation (Maguvu *et al.*, 2013). Moreover, it also prevents the activity of ACC oxidase and ACC synthase that helps in controlling ethylene synthesis. On the other hand, silver nitrate ($AgNO_3$) is one of the salts of silver that is commonly used in preservative solution for vase life improvement (Khella *et al.*, 2018). Ag^+ in silver nitrate helps in preventing ethylene activity by blocking the special receptors present on the cell membrane (Kiamohammadi and Hashemaabadi, 2011). As silver also has antimicrobial activities, it reduces the vascular tissues blockage by bacterial growth, increases water uptake and enhanced vase life (Ha *et al.*, 2017). Whereas minimum vase life in control treatment was due to the absence of food source, bactericide and biocide in a preservative solution that are the main elements for supporting the life of cut flowers after harvest (Maguvu *et al.*, 2013). Combination of both sucrose and silver nitrate in preservative solution improves vase life in rose 'Black Magic' (Abdel-Kader *et al.*, 2017), gladiolus 'Yellow Stone' (Awasthi *et al.*, 2013) and orchid (Ajithkumar *et al.*, 2013).

The preservative solution containing $AgNO_3$ (250 ppm) + sucrose (3%) not only increase vase life but also helps in improving flower opening percentage, days to open basal floret, bloom spread, floret length, floret diameter, floral spike fresh and dry weight, and fresh weight loss. Similarly pulsing of cut flowers with sucrose and biocides combination increased floret opening in lisianthus (Kiamohammadi and Hashemaabadi, 2011), bird of paradise (Gendy and Hamad, 2011), orchid (Mattiuz *et al.*, 2015), tuberose (Kumar and Deen, 2017) and gladiolus (Casares *et al.*, 2017). Like floret opening percentage, Ahmed *et al.* (2018) observed that biocide (Aluminium sulphate) and sucrose induce early opening of basal florets in *Gladiolus hybridus*. Sucrose along with other various functions also helps in stomatal closure thus preventing water loss ultimately increases fresh weight (Abdulrahman *et al.*, 2012). Germicidal and ethylene inhibition properties of $AgNO_3$ increased the fresh weight of cut tuberose and rose 'Red One' when their cut stem was treated with silver nitrate solution and sucrose solution (Mirjalili, 2015; Kumari *et al.*, 2018).

Senescence in cut flower is mainly attributed to petals wilting that occur due to an imbalance between uptake of water and transpiration loss along with decreasing supply of food (carbohydrates). In this experiment, a minimum floret wilting percentage was recorded in a preservative solution having $AgNO_3$ (250 ppm) + sucrose (3%) which may be due to ethylene inhibition and biocidal activity of silver ions (Ahmad *et al.*, 2013). Also due to sucrose that causes an increase in starch concentration, as starch is an indication of carbohydrates (food) availability to the petals thus providing energy for florets to retain their freshness. Role of Ag in an alleviation of bacterial growth at the stem end of gardenias improves water uptake and subsequently delays wilting rate (Lin *et al.*, 2019). In yellow gladiolus, pulsing of floral spikes with preservative solution containing sucrose and silver thiosulphate (STS) extend the longevity of basal florets (Uddina *et al.*, 2016). However highest wilting percentage examined when sucrose (3%) was used as the preservative solution, this may be due to rapid break down of sugar combined with quick water loss through transpiration results in early senescence of florets (Chathuri and Sarananda, 2011) or may be due to highest bacterial activity at stem base that limits the water uptake by cut spike which depletes food reserves which leads to petal fading and cell flaccidity (Thwala *et al.*, 2013). In *Acacia holoserica* cut foliage, application of exogenous sucrose leads to accumulation of high sucrose concentration in the apoplast of leaf cells that cause the cells to plasmolyse thus damage cells and ultimately results in the death of foliage (Mohd Rafdi *et al.*, 2018). Also in calla lily, Sales *et al.* (2018) reported that high sucrose concentration causes phytotoxicity or initiate a physiological process that leads to early senescence.

Cut flowers ability to absorb solution depends on three basic factors such as transpiration, respiration and type of compounds dissolved in a solution and it decreased with the aging which ultimately affects cell turgidity (Babarabie, 2018). Maximum uptake of a solution was recorded in $AgNO_3$ (250 ppm) solution whereas cut spikes dipped in sucrose (3%) uptake minimum amount of preservative solution. Higher water uptake by floral spikes under silver nitrate treatment was attributed due to the acidifying effect of $AgNO_3$ which lowers the pH of a preservative solution, thus it only inhibits the ethylene biosynthesis but also reduced the bacterial growth/proliferation (Bajpay and Dwivedi, 2018). Reduced total solution uptake was due to higher sucrose concentration that decreased water potential in cut spikes and thus decreases the uptake of preservative solution (Bharathi and Barman, 2015). Although sugar in preservative solution helps in thickening of a cell wall and vascular tissues lignifications it also promotes bacterial growth in solution which results in blockage of vascular tissues that reduced solution uptake by the spikes (Patel *et al.*, 2016). Our results are in accordance with Kantharaj *et al.* (2018) who observed that 1.5% sucrose results in minimum water uptake and solution balance in gerbera 'Julia'. $AgNO_3$ treated carnation 'Tabour' cut flower consumed the maximum solution of up to 36.56 ml as compared to distilled water and STS treatment (Sharma and Bhardwaj, 2015). In gerbera 'Dune', 300 mg L^{-1} concentration of $AgNO^3$ uptake 64 ml of preservative solution (Abadi *et al.*, 2013) and in gladiolus 'White Prosperity' 63.3 ml of solution was uptake by a spike when held in $AgNO_3$ 20 mg L^{-1} concentration (Ahmad *et al.*, 2016). Like total solution uptake, solution balance was also maximum in $AgNO_3$ (250 ppm) treatment and minimum in sucrose (3%). Highest water balance in cut spikes of gerbera "Alppraz" flower was observed in holding solution containing sodium hypochlorite 20 ppm (Hema *et al.*, 2018). Solution balance in cut spikes was changed when there was an imbalance in solution uptake and transpiration rate (Ha *et al.*, 2017). The reason for the change in imbalance was a high concentration of sucrose that causes osmotic stress in flowers (Dung *et al.*, 2017) along with increase microbial multiplication that leads to xylem vessels blockage (Yagi *et al.*, 2014).

Results related to the response of different gladiolus cultivars towards preservative solutions vary from variety to variety. Timmerman and Kroon (2009) reported that vase life of cut flowers not only varies between species of different plants but also varies between varieties of the same species. 'White Prosperity' and 'Tissue' showed least effective results which may be due to their genetic makeup as they are more susceptible to bacterial infections or have limited ability to withstand bacterial attack on end stem and has reduced potential to uptake mineral nutrients and uptake from solution whereas 'Alexandra' performed better in response to all parameters which was may be due to variation in xylem vessels anatomy that greatly affects the hydraulic conductivity (Gebremedhin *et al.*, 2013) which results in more uptake of a preservative solution and more growth and expansion of cells of petals. Our results are in accordance with Kazuo *et al.* (2005) who examined that sucrose and 8-HQS treatment improves post-harvest life of rose cultivar, 'Delilah' as compared to 'Sonia' because of higher soluble carbohydrates concentration in petals. In another experiment, Shabanian *et al.* (2018) observed that gerbera cultivar "Bayadere" had longest vase life than "Sunway" due to its ability to resist oxidative stress and high potential to uptake water from preservative solution.

In the present research, enhanced vase life under polyethylene packaging may be due to reduced permeability of polyethylene material. Reduced permeability to moisture and air causes a decrease in the cell division process and respiration rate which results in the reduction of weight loss thus ultimately increases water balance of gladiolus spikes (Varu and Barad, 2008). Moreover, the minimum wilting percentage of cut spikes under the same packaging material was also due to the development of a modified atmosphere that maintained high humidity, CO_2 and low oxygen levels inside the packaging material that slows down the transpiration rate and retains high water content. This in return increased floret freshness and turgidity (Prashanth and Chandrasekar, 2010). Furthermore, dry packaging using polyethylene sheet controlled the microorganisms (bacterial) growth at the base of cut spikes and prevent vascular blockage and increase water uptake (Amin, 2016). In marigold flowers, low-density polyethylene packaging increased vase life up to 8 days as compared to 4 days in control packaging (Pal *et al.*, 2016). The packaging of rose "First Red" cut stems with the polyethylene sheet and corrugated fibre board box improves flower opening, vase life and overall quality (Bhaskar and Rao, 2018).

CONCLUSION

Overall results concluded that cut spikes of Alexandra variety dipped in the preservative solution of $AgNO_3$ (250 ppm) and Sucrose (3%) and packed in polyethylene sheet gives the best results in terms of vase life and postharvest keeping quality. Therefore it is suggested that this preservative solution combination and packaging material can be used commercially to enhance vase life of other economically important cut flowers.

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